To Dr. Wilkins with my kind compliments

C. G. Hughes 6/12/55

BUREAU OF SUGAR EXPERIMENT STATIONS

BRISBANE

QUEENSLAND

TECHNICAL COMMUNICATIONS.

YEAR 1955, No. 2

Ratoon Stunting Disease of Sugar Cane

by

C. G. HUGHES and D. R. L. STEINDL

Issued by Direction of the
Sugar Experiment Stations Board

JAN 1956

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Ratoon Stunting Disease of Sugar Cane

By C. G. HUGHES AND D. R. L. STEINDL

INTRODUCTION

Towards the end of 1944 reports were received from officers of this Bureau and individual farmers in the Mackay district that the new and promising seedling cane Q.28 was ratooning very poorly on many farms, chiefly centres about the Racecourse-Walkerston-Rosella area. The variety which had been propagated from an original seedling grown on the Mackay Sugar Experiment Station in 1935-1936, from seed of the cross Co.290 x Q.1098 obtained in North Queensland in the winter of 1935, had already proved itself in the Mackay district and was regarded as an outstandingly useful cane, particularly in the rather poorly drained, clay-bottomed land. Farmers had sent only 2,400 tons of Q.28 to the mills for crushing in 1943, but in the 1944 season 111,000 tons were crushed and the total was to exceed

Fig. 1—Both diseased and healthy sources of planting material were used when the farmer planted this block.

800,000 tons in 1948, until then the largest crushing of a single variety ever recorded in the district; the combined effects of ratoon stunting disease and the advent of Q.50 later reduced the variety to one of minor importance. There was naturally some cause for concern in the closing months of 1944 that a cane of such potential should be in danger of being lost on account of poor ratooning.

The senior author visited the area in January, 1945, and found that the reports of poor ratoons were not exaggerations. On many farms crops which had been cut up to four months previously were extremely backward although still alive and apparently in sound condition. The rainfall records showed that in the five months,

August to December, only 4½ inches had fallen, in comparison with the average of 14 inches, but the drought could not be considered the prime cause when it was discovered that in some fields, which had been planted with setts from different sources, one batch of plants was yielding satisfactory ratoons while the other was not. Some skirmish trials to test the usual methods of control, such as treatment of the setts with fungicides and treatment in water at 52° C. for 20 minutes—the standard method of inactivating chlorotic streak in setts [5]—were planted in 1945 and 1946, but no indications were given of a possible line of attack on the problem.

A district survey by officers of the Mackay Cane Pest and Disease Control Board in 1947 showed that the disease was widespread and that very serious losses in yield were being caused; incidentally it also showed that certain sources which had been used to provide plants on an extensive scale were in fact infected with the trouble. There was as yet no proof that the disorder was a disease, or if it were, it appeared to be confined in the present instance to the variety Q.28 and

Fig. 2—Young ratoon trial at Mackay. Plot of diseased Q.28 in the foreground, healthy in the rear.

the terms "Q.28 trouble" or "Q.28 disease" came into common use amongst farmers and investigating officers alike. The term "ratoon stunting disease" first appeared in print in 1949 [46], although the name had been used by the present authors in the previous year.

Observations into at least the first ratoons, and on occasions into the second ratoons, had shown that on some farms the Q.28 had probably remained free from disease and these sources were used in 1947 in initiating a series of experiments and yield trials. Results from the latter are discussed in the section below devoted to stunting symptoms. The experiments had to be continued into the ratoons before any conclusions could be drawn, but by the early part of 1949, when the ratoon plots were approximately six months old, it became apparent that the stunting in Q.28 was due to a transmissible disease. Setts of Q.28, from a source known to produce healthy ratoons, inoculated with juice from diseased stalks of

Q.28 by pressure [6] into the freshly cut ends, produced ratoons which showed the stunting typical of the disease. The control plots of non-inoculated setts gave normal ratoons. In addition, transmission per medium of the cutting knife was clearly shown when healthy sticks were fed into a cutter planter following its use with diseased stalks.

Comparatively early in the investigations it was noted that affected stalks showed discoloured vascular bundles in the lower parts of the nodes when the stalks were sliced lengthwise with a sharp knife, but little importance was attached to the discovery at the time since similar effects were also found in stalks of both Q.28 and other varieties which were, as far as was known, free from the disease. Later experiments, however, established this vascular discolouration as a definite diagnostic symptom.

Further investigations have shown that this vascular discolouration is an accurate indication of infection, although its absence does not necessarily guarantee freedom from the disease. Some confusion is possible at times with discolouration caused by other conditions and on occasions nodes are darkened so much by various unknown factors that the discolouration is masked but, in general, the trained observer can regard it as the most reliable diagnostic feature of the disease. This symptom alone was used in a survey through every mill area in Queensland in the spring of 1952 and the findings have not in any instance been rendered invalid by subsequent work.

Ratoon stunting disease was thought at first to be confined to the Mackay district, but examination during 1948-1949 of crops of Q.28 in the Bundaberg and Maryborough-Bauple areas in South Queensland and in the Proserpine district near Mackay revealed that the variety was also infected in these areas. The survey of 1952 showed the disease to be present in every mill area in Queensland and in practically every variety on the approved variety lists.

The use of planting material from fields with a history of satisfactory ratooning under non-irrigated conditions, and the sterilization of knives when moving into apparently healthy fields, were control measures which served a useful purpose in keeping some check on the spread of the disease, but it was not until hot-water treatment had been found to render setts disease-free that it was possible to initiate full control measures against the disease. The campaign started in a very small way in 1952, but in the following year 2,115 tons of plants were treated in special tanks in the various mill areas.

DISTRIBUTION

It has been established that ratoon stunting disease occurs in every mill area in Queensland. More detailed studies of the distribution in the various mill areas would be of little import since there is usually a fairly free movement of planting material between individual farms in the one area; nevertheless such studies were made in the Mackay district, where the disease was first found, in the course of early investigations into the problem. It was apparent there that several localities were free from the disease, and many farms in these places have remained quite free, although continuing to grow Q.28. There are indications that some localities in other mill areas may have remained free from the disease but, in general, these are not sufficiently extensive to be of great importance in campaigns aimed at control; this is especially the case when doubt exists that the fields intended for use as sources of plants may not be as clean as would appear, and that the disease may still be present in canes which do not show symptoms readily.

Following the discovery of ratoon stunting disease in commercial cane crops the question arose as to whether the numerous plantings of cane made for fodder for cows and other farm animals in non-canegrowing districts carried the disease. These plantings are usually quite small on individual farms, but since they do not

represent any disease menace to commercial production they generally do not come within the scope of the disease controlling activities of the Bureau or its auxiliary Cane Pest and Disease Control Boards. Consequently, they are frequently badly diseased, and damage by Fiji, mosaic, and leaf-scald diseases is recorded from time to time. However, examination of cow canes from several districts has shown them to be free from ratoon stunting disease. This could of course be due to high resistance to the disease and a series of "cow canes," as these fodder canes are called, is included in the current disease resistance trial in order to test their resistance.

Apart from a few experimental plantings on a research property in Western Australia, the cultivation of commercial sugar canes in Australia is confined to Queensland and the neighbouring Northern Rivers District of New South Wales. The activities of Bureau pathologists do not extend to the New South Wales cane growing areas but through the courtesy of the Colonial Sugar Refining Company, which owns the three mills there, specimens of suspect cane were brought to Brisbane, when they were diagnosed as having typical ratoon stunting symptoms. Subsequent reports have indicated that the disease is widespread in each mill area.

Personal examination in the countries mentioned by one of the authors [60] has shown that the disease is present in Hawaii, Louisiana, Florida, Jamaica, St. Kitts, Antigua, Barbados, Trinidad and probably present in British Guiana. An examination by King [33] revealed the disease in Colombia while the same author confirmed its presence in South Africa after canes imported from that country had shown reddened vascular bundles after growth in this Bureau's Brisbane quarantine house. Similar symptoms have been seen in canes received from the collection of the United States Department of Agriculture at Canal Point, Florida, and from India.

A report from Taiwan [26, 27], following a visit by Ju-chi Chou to the Bureau's Pathology Farm near Brisbane towards the end of 1953, indicates that the disease is widespread in that country. Abbott reported the disease in Mexico [1] and it is also present in Puerto Rico [56], the Philippines [41], and Nicaragua. Orian is of the opinion that it occurs in Mauritius [54] and Barat [2] was able to confirm this following a visit to Queensland, where he became familiar with the characteristic symptoms.

Although the disease is so widespread in commercial cultivation in many countries it apparently does not occur in New Guinea, where sugar cane is a mall-garden crop. An expedition in 1951 [11] brought back 165 varieties from various parts of the island and of these over 120 became established in Queensland and have now been observed in plant and ratoon crops without any development of ratoon stunting symptoms.

SYMPTOMS

Ratoon stunting disease does not show any specific external features such as are to be found in the majority of other diseases; its external expression takes the form of a general stunting which can be caused by a wide range of other factors, and it is only by elimination of all these that a diagnosis of ratoon stunting can be made. This is at best a difficult operation and even in special trial plantings individual stool variation may be so large that the plots have to be replicated before the significance of differences can be proved. All the experimental work initiated in the first three or four years following the discovery of the disease in the early part of 1945 suffered from this disadvantage (as well as from the necessity always to take plots to at least first-ratoon maturity) and progress was necessarily slow on these accounts. If the detection of ratoon stunting losses were difficult in experimental plots with adequate controls, they were doubly difficult in block plantings on commercial farms, for in these instances the possible operation of such cultural handicaps as poor drainage, poor cultivation, wrong time of planting, poor

plants, inadequate moisture or fertilizer and late harvesting were added to the lack of control plantings. As it happened, however, it was chance plantings of setts from healthy and what are now known to be diseased sources on several farms which first suggested to workers on the problem that a disease was involved.

The internal symptoms of ratoon stunting which prevent it being classified in the small, select group of symptomless diseases, consist of a discolouration in the vascular tissue at certain points in the nodes of mature cane and a general pink discolouration in the very young nodes towards the growing point of small shoots and suckers.

STUNTING AND REDUCTION IN YIELD.

a. In Plant Crops.

The general symptom of stunting due to the disease varies considerably from one variety to another; some canes suffer severely in both plant and ratoon crops, others principally in ratoons, whilst a few remain comparatively unaffected in both

Fig. 3—Diseased and healthy P.O.J.2878 in adjacent beds of the same block on a farm at Mackay.

crops. Knowledge of reactions in the plant crop is as yet somewhat limited, since apart from information on the disease in Q.28, in which variety the disease was first discovered, the only opportunities afforded for critical comparisons of yielding capacity between diseased and healthy material have been provided by the series of replicated trials planted in 1953 and harvested in 1954.

The planting of diseased setts of Q.28, which is at least as susceptible as any cane grown commercially in Queensland and a good deal more susceptible than most, gives a comparatively slow and erratic germination. The total sett germination is usually not unsatisfactory, nor significantly less than in the disease-free plots, but the rate of germination is considerably depressed, so that at any given time during germination the healthy will have more shoots above ground than the diseased. Numerous counts have been made on comparable plantings and typical figures are given in Table I. These are for randomized block plantings at Mackay $2\frac{1}{2}$ to $3\frac{1}{2}$ months after planting, and although only averaged results are set out the analysis showed that the differences were significant.

TABLE I
Shoots per Plot at 2½ to 3½ Months after Planting

Trial	Healthy Plots	Diseased Plots
1	274	201
2	303	287
3	689	595

The behaviour of other commercial canes varies from variety to variety: some, such as Pindar, P.O.J.2878, Q.47 and Trojan generally give a better germination and better early growth when healthy plants are used, but others, of which Badila, Q.50 and S.J.4 are examples, do not appear to be affected by primary infection in the early stages of growth, and variations between comparable plantings of diseased and healthy material are probably independent of the disease.

Fig. 4—Young plant trial at Mackay. Healthy Pindar on left, diseased Pindar on right.

Where uneven and slower germination is apparently due to the disease it cannot be corrected by extra attention to cultural details or by pre-planting treatment with a mercurial solution [17] and in itself is a source of loss to farmers. It makes necessary extra weeding operations as the stand is being established and delays the important weed-smothering, covering-in of the cane foliage along and between the rows.

Diseased plant crops of susceptible varieties show the effects of dry weather before healthy ones; not only does visible growth cease sooner in the diseased crop as the soil moisture becomes depleted, but symptoms of distress such as wilting during the hot hours of the day, scorching of the tips and edges of the leaves, and

premature death of the older leaves, also show earlier. Isolated observations have indicated that waterlogging of the soil might also have a more serious effect on diseased plants.

The slower germination and less vigorous early growth does not necessarily mean that the stooling, or number of stalks per stool in the mature plant crop is reduced in the diseased plots. The trials with Q.28 which were planted in 1947, a year when the rainfall was much less than normal during the spring and early summer, indicated a reduction in stooling with that variety, but the series of trials planted in 1953, when rainfall was generally adequate, showed no effect on ultimate stooling in the varieties N.Co.310, Pindar, P.O.J.2878, Q.50 and Trojan. The harvest results showed that Q.50 did not always suffer yield losses in these trials, but the other varieties mentioned were seriously affected. An interesting observation in connection with this lack of depression of stooling as between healthy and diseased series of plots in the replicated trials is that experienced cane inspectors are frequently convinced that the diseased cane does not stool as well as the healthy; this may be explained by the fact that the stools in the healthy plots do appear to have more cane, or more stalks showing mature cane, than do the diseased in which the stools are not so uniform. The slower early growth in the diseased plots is responsible for the production of stools made up of stalks of widely varying ages, while the comparatively uniform germination in the healthy leads to stools with stalks of more even size.

Figures for stalk length obtained for the varieties N.Co.310, Pindar, P.O.J.2878, Q.50 and Trojan, in trials in the Mulgrave, Giru and Mackay areas show that ratoon stunting disease may have a serious stunting effect even in the plant crop. A study of the figures in Table II discloses highly significant differences between the healthy and diseased series in replicated trials for Pindar, P.O.J.2878 and Trojan, while N.Co.310 gave a significant difference in the one trial in which it was included, and Q.50 gave a similar order of significant difference in the same trial; in another experiment in which both Pindar and Trojan gave highly significant differences, the healthy Q.50 was not statistically superior to the diseased.

TABLE II

Length of Stalk in Inches in Diseased and Healthy Plots
Plant Cane

Trial Location		Mulgrave	Giru	Mackay	Bundaberg
N.Co.310	Healthy				98.5
	Diseased				94.5
	Difference				4.0†
Pindar	Healthy	102.7	103.4		
	Diseased	89.6	95.1		
	Difference	13.1	8.3†		
P.O.J.2878	Healthy			90.5	
	Diseased			84.8	
	Difference			5.7	
Q.50	Healthy	103.6			97.7
	Diseased	101.1			92.8
	Difference	2.5*			4.9†
Trojan	Healthy	91.8	93.3	82.7	
	Diseased	75.4	81.4	75.8	
	Difference	16.4	11.9†	6.9	

†Difference significant at 5 per cent. level. *Difference not significant.
All other differences significant at 1 per cent. level.

Measurements of stalk diameter made one-third from the base of the stalks in these trials did not indicate any significant differences between diseased and healthy plots and it appears that the losses in tonnage in the plant crops of the varieties discussed are primarily due to the production of shorter stalks by the diseased stools.

The plant crop losses which can occur in the susceptible variety Q.28 have been known for some time [61], but comparable figures for other varieties were not available until the trials planted in 1953 were harvested in the latter half of the following year. Figures for Q.28 from trials harvested in 1948 and for N.Co.310, Pindar, P.O.J.2878, Q.47, Q.50 and Trojan in trials harvested in 1954 are set out in Table III. Full details of these trials are included in the Appendix.

TABLE III

Yields of Diseased and Healthy Plots in Replicated Trials
Plant Crop, Tons per Acre

	N.Co.310	Pindar	P.O.J.2878	Q.28	Q.50	Trojan
Healthy ..	34.75	47.9	30.75	28.6	46.1	45.8
Diseased ..	28.3	40.9	26.3	17.9	46.4	34.3
Loss ..	6.45	7.0	4.45†	10.7	—*	11.5
Healthy ..		41.7		36.0	36.8	43.2
Diseased ..		35.8		27.3	35.0	33.4
Loss ..		5.9		8.7	1.8*	9.8
Healthy ..		25.1		30.2	32.1	37.0
Diseased ..		21.9		23.9	27.65	29.6
Loss ..		3.2†		6.3	4.45†	7.4
Healthy ..				40.1		
Diseased ..				33.1		
Loss ..				7.0		
Healthy ..				37.3		
Diseased ..				33.0		
Loss ..				4.3†		

† Difference significant at 5 per cent. level.

* Difference not significant.

All other differences significant at 1 per cent. level.

Fig. 5— Diseased Q.28 ratoons on the left, healthy on theright. Diseased cane in this trial averaged 11.4 tons per acre, healthy cane 29.2.

Results listed in Table III warrant the conclusion that, even in the plant crop where losses are known to be generally lighter than in the ratoons, ratoon stunting disease can be expected to depress yields of cane seriously in N.Co.310, Pindar, Q.28 and Trojan, while P.O.J.2878 may suffer losses. The figures for Q.50, which show no significant losses in two trials, and a difference between healthy and diseased significant only at the 5 per cent. level in a third trial, indicate a high degree of tolerance in this variety, a conclusion borne out by observations in the field in the Mackay district. Observations in South Queensland, however, particularly on the drought-liable slopes of the Isis area, indicate that Q.50 suffers losses there; it may

Fig. 6—Second ratoons of a seedling cane at Bundaberg affected with ratoon stunting disease. The plot in the background of the comparatively resistant Q.50 was cut at the same time.

be worthy of note that the trial in which the Q.50 showed a loss was on a soil type similar to the Isis, although practically level, and was in the neighbouring South Queensland district of Bundaberg.

Figures for sugar content were obtained in all trials but no clear pattern of significance emerged.

b. In Ratoon Crops.

Losses in the variety Q.28 in the plant crop can be quite appreciable, as has been shown, but it is the serious losses from stunting in the ratoons which give to the disease its descriptive name. Detailed information on the effects of the disease on ratoon crops are available only from replicated experiments with the variety Q.28, but other varieties have been observed in diseased commercial plantings and in small plots in the disease resistance trials, and then the susceptible varieties appear to follow much the same pattern as Q.28 in their reaction to the disease.

The young diseased stand does not show any particular features following the usual ratooning practices of disc harrowing, grubbing, fertilizing and surface cultivation. The stools all appear sound both in the visible stubble and in the rooting system and everything appears to be in order for the production of a satisfactory crop. In well watered but well drained soil the shoots will come away normally within a reasonable time, but if the field cannot be irrigated, and the dry spring and early summer which characterise the Queensland sugar areas eventuate, the ratoon stubble remains practically dormant. Diseased crops, cut and ratooned in September, have moved so slowly on occasions that by the end of the following January, *i.e.*, some four months later and just prior to the commencement of the wet monsoon, they gave the appearance of having been ratooned for only two or three weeks. The largest shoots were not more than 18 inches or so in height, although it was noted that very few of the stools had died. Besides being smaller than normal, these shoots were fewer in number in diseased fields, a fact well shown by the figures for randomised block trials set out in Table IV. Stools ratooning are also included in the Table, although differences between the diseased and healthy series were not significant. The counts were made seven to ten weeks after cutting and ratooning and each figure is an average of all the plots in the particular series. Plots in these trials were approximately 1/15 acre and it is obvious that the stands in all these trials were quite satisfactory.

TABLE IV

Stools and Shoots per Plot. Young Ratoons. Variety Q.28.

Trial	Healthy Plots		Diseased Plots	
	Shoots	Stools	Shoots	Stools
1	1694	252	908	226
2	4114	357	1620	318
3	3434	366	2396	326

As in the plant crop, the initial disadvantage of the diseased plots in the ratoons is never overcome and these plots continue to lose ground in comparison with the healthy as the season advances. The diseased cane cannot make use of the ideal conditions of the hot wet season and instead of growing rapidly, fails to stool and cover in properly and so becomes infested with a vigorous population of weeds and grasses, which soon put an end to any hope of useful growth in the cooler autumn and winter. The stunted stools contain fewer sticks, and these are shorter than normal with a light, inadequate top and general unthrifty appearance. The stunting is not uniform from stool to stool and diseased fields show a characteristic "up and down" appearance. In commercial plantings some of this might be due to the fact that not all setts were equally infected when planted, but the same thing occurs in experimental plantings using all diseased material. The explanation may lie in variations in the micro-environment of individual stools since it has been found that the larger stools, as far as can be judged by internal symptoms and some limited propagations are, in many instances, just as heavily infected with the causal agent of the disease as are the smaller stools. There is no indication that the larger stools are due to recovery from the disease, for recovery has not been recorded in the many plantings kept under close observation for at least plant and first-ratoon crops.

The fields of diseased cane are unduly sensitive to even slight decreases in soil moisture and show wilting during the heat of the day when comparable healthy crops are still turgid. They also show drought symptoms, such as wilting and death of leaf tissue, much sooner than expected, and in general the impression is given that the disease has caused serious upsets in the water economy of the plant.

Under normal conditions in the Queensland cane areas there is little death of diseased stools in mature cane during the winter and early spring and even when whole fields are a uniform tinder brown, without a trace of green, a close examination will show that the stalks are still sound and alive. The disease does not cause the death of the apical growing point until the plant as a whole is very close to death and this fact, combined with a lack of lateral bud stimulation, means that the terminal dominance is maintained until the end, and no side-shooting occurs. If diseased crops are left for a late harvest in a dry season, or attempts are made to standover and unseasonal dry weather supervenes, the proportion of stools dying may so rise that the field is a commercial loss. This is a real risk in many areas where the recognized practice is to harvest late, or to standover any backward crop.

Fig. 7—Typical irregular appearance of young ratoon diseased fields of Q.28.

Losses in ratoons have been demonstrated in many trials with the variety Q.28 but results with other commercial canes are not yet to hand, although the indications are that losses in some at least of these, *e.g.*, N.Co.310, Pindar, P.O.J.2878, Trojan and Vesta, may be of the same order as in Q.28. A series of replicated yield trials with Q.28 was laid down in the Mackay district during the spring planting season of 1947. Results from these provided the first definite information as to the losses which the disease could cause in that variety, even though knowledge of the disease was not sufficiently advanced to guarantee that the so-called "healthy" material was in fact wholly free from the disease. Diseased material was taken from fields with a record of poor yielding ratoons, and healthy from fields known to have yielded well in at least the first ratoon and sometimes the first and second ratoons. It was fortunate that contamination had remained low during the growth of these selected healthy fields since infection at the cutting of the previous crop would probably not have been obvious before the plants were cut; on the other hand, many of the healthy plots did become somewhat infected by the cutter planter at planting. The

net result, however, was that in all the trials the healthy plots were substantially but not wholly free from the disease and allowed an adequate although somewhat conservative assessment of the losses to be expected from the disease.

This early series of trials was harvested in the following spring (q.v. above) and ratooned and fertilized in the normal manner.

There was generally sufficient soil moisture to ensure establishment of the young ratoons and the subsequent rain, although less than normal in the aggregate, was so evenly distributed that the Mackay district average tonnage per acre was above normal. Two of the trials, which also showed a considerable amount of

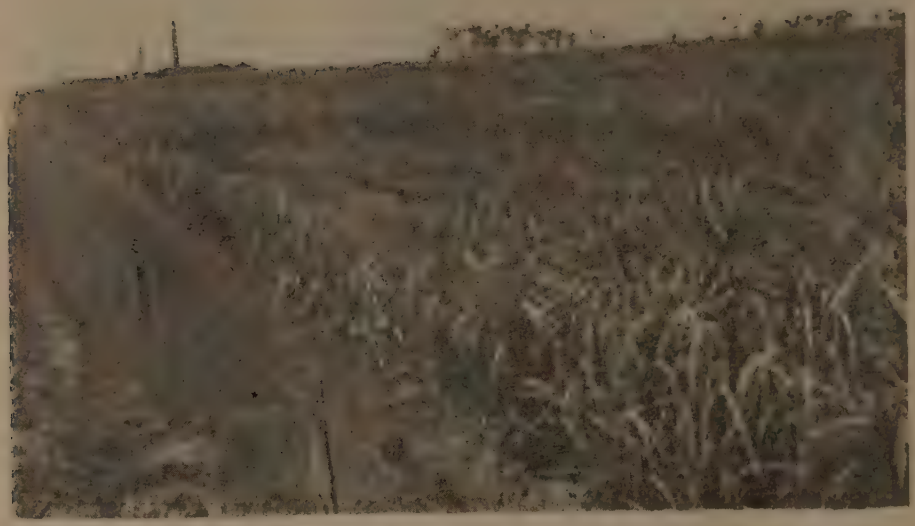

Fig. 8—Ratoon stunting disease loss trial at Mackay. The replicated diseased plots can be clearly seen Variety, Q.28. Crop, first ratoon.

TABLE V

Healthy and Diseased First Ratoons of Q.28

Trial		Yield	Loss	
			Tons per acre	Percentage
1	Healthy	27.6		
	Diseased	9.6	18.0	65.2
2	Healthy	20.5		
	Diseased	7.5	13.0	63.4
3	Healthy	17.0		
	Diseased	10.0	7.0	41.2
4	Healthy	29.6		
	Diseased	11.4	18.2	61.5
5	Healthy	30.3		
	Diseased	10.0	20.3	67.0

disease in the healthy series (see Table V) did produce only average ratoon crops, but the other three gave abnormally heavy yields in healthy plots. However, the good growing conditions aided by an open winter extending right until harvest, still failed to produce a reasonable crop in the diseased plots, and differences which were fully significant at the 1 per cent. level were recorded in all trials. The tonnage losses are in themselves serious but they do not represent the total financial loss to the farmer, for the diseased plots on the basis of the first-ratoon results would have had to be ploughed out, while there would have been every prospect of a second and even perhaps a third ratoon from the healthy cane. In addition, the Awards which govern the payment for harvesting and loading sugar cane make provision for progressively increasing the payment per ton as the crops fall below a certain specified tonnage per acre. Estimating the direct ratoon losses on the average of the five trials quoted in Table V, the difference of 15.3 tons per acre would represent a loss per acre to the farmer of £70/6/–, made up as follows:— 15.3 tons at £4/10/– (an average price for cane) plus £1/9/–, representing the difference in harvesting rates of 13/10½ per ton for 25 tons per acre crops and of 16/11 per ton

TABLE VI

Reaction of Approved Varieties to Ratoon Stunting Disease

Variety	Yield Losses	Internal Symptoms
Atlas	—	—
Badila	moderate	variable
Badila Seedling	—	variable
B.208	—	variable but apparently disease-free stalks often show dark cream bundles
C.P.29/116 ..	small	often difficult to find, never very obvious
Cato	moderate to severe	—
Clark's Seedling	—	obvious
Co.290	—	obvious
Co.301	small	obvious
Comus	probably small	variable, but apparently disease-free stalks often show dark cream bundles
E.K.28 ..	—	—
Eros	moderate	obvious
M.1900 S. ..	severe	obvious
N.Co.310 ..	severe	obvious
Pindar	moderate to severe	obvious
Pompey ..	—	—
P.O.J.213 ..	—	—
P.O.J.2725 ..	moderate to severe	variable
P.O.J.2878 ..	severe	variable
Q.25	—	—
Q.28	severe	obvious
Q.42	severe	obvious
Q.44	small	obvious
Q.45	severe	obvious
Q.47	moderate	variable
Q.49	severe	obvious
Q.50	variable, severe S.Q. small, Central Q.	often difficult to find
Q.51	severe	obvious
Q.55	severe	obvious
Q.57	small	difficult to find
Q.813	severe	often difficult to find
Ragnar	—	—
S.J.2	severe	often difficult to find
S.J.4	severe	variable
S.J.16	severe	obvious
Trojan	severe	obvious
Vesta	severe	variable
Vidar	severe	obvious

for 9.7 tons per acre crops. To this loss must be added the cost of replanting at least one year before reasonably expected and of the extra cultivations rendered necessary by the seeding of weeds growing in the light, open crop. Even supposing that the plant crops did not suffer any losses, a farmer harvesting a total of 1,000 tons of cane per season, of which on a State-wide average figure some 550 tons should be expected from approximately 22 acres of ratoons, would suffer a loss of more than £1,540. This could easily represent the difference between prosperity and insolvency in a budget with gross receipts of £4,500.

Although results are not yet available from the current series of trials, observations in the field and in small-scale resistance trials have indicated a wide range of susceptibility to the disease among the standard Queensland commercial canes. The yield losses to be expected under ordinary farming conditions in Queensland are indicated in Table VI for varieties approved for planting in Queensland in 1953.

Fig. 9—Healthy Trojan ratoons on the left, diseased on the right, in the one commercial planting at Mulgrave.

An examination of the root system of diseased stools does not reveal any features of diagnostic interest, although inoculations with extracts from roots have shown that the causal agent is present there. The general root mass is much reduced in size, which is only to be expected when the above-ground parts are so much smaller than normal, and the diseased stools are much easier to pull out of the ground. The reduction is not confined to one type of root and the buttress and rope systems suffer as severely as the fibrous surface-feeding type. What roots there are appear to be normal and there is no evidence that any soil-inhabiting organism is associated with the disease.

As would be expected with a disease in which infection of diseased planting material is the chief means of spread, ratoon stunting does not occur in patches in a field although on occasions a gravel area in an otherwise uniform field will accentuate the effects of the disease. Either whole fields or sections of fields, corresponding with the planting of diseased setts, are affected. Gradations in

Fig. 10—Internal symptoms of ratoon stunting disease.

Left to right:

Top row: Immature diseased and healthy nodes.

Bottom row: Mature diseased and healthy nodes.

infection can occur over the full range from an odd stunted stool in the block of otherwise healthy cane to an odd apparently healthy stool in a field of stunted cane.

Variations in cultural technique such as deeper ploughing, more intensive cultivation, extra fertilizer, etc., do not have any effect in reducing the stunting of diseased cane but adequate irrigation, particularly in the early stages of growth, may mask it during the plant crop and to some extent during the ratoons, although with varieties as susceptible as Q.28 and Vesta the stunting is still obvious to the experienced observer. While adequate moisture tends to prevent losses, excessive moisture, which gives a so-called physiological drought due to reduction and stagnation in the soil atmosphere, has the reverse effect and badly damaged diseased fields are frequently found in damp places.

INTERNAL DISCOLOURATION.

Two types of internal stalk discolouration are commonly found associated with ratoon stunting disease; one is seen in nodes of mature or comparatively mature cane and consists of a discolouration of individual vascular bundles, the other is found generally as a pink colour in the nodes of very young cane. The former has been used more extensively in identifying the disease than has the latter, which is only a comparatively recent discovery, the uses and reliability of which have not yet been fully established.

The early investigations into ratoon stunting were hampered by the lack of knowledge of any readily observable diagnostic feature, and the positive identification of the disease depended on inoculation into setts of the susceptible Q.28, and growth into the first and sometimes the second ratoons. Discoloured vascular bundles were first mentioned as symptoms of the disease in 1950 [58] although they had been observed some time before. Early work had shown their presence in diseased canes, but unfortunately at that time they were also found in what were thought to be healthy stalks and it did not seem feasible that they would be of diagnostic value. However, a selection of stalks of Q.28 on the basis of the presence or absence of discoloured bundles in the basal nodes gave, on the one hand, a badly stunted crop and, on the other, a crop in which the greater number of stools were perfectly normal and apparently disease-free. Subsequent examinations of diseased and healthy material of a large range of varieties have indicated that the discoloured bundles are a reliable indication of the presence of the disease, although inability to find them does not necessarily mean that the disease is absent. This evidence as to the presence of the disease when bundles are discoloured has been further confirmed by inoculation tests in which many canes inoculated with juice from Q.28 stalks showing this symptom subsequently developed the characteristic discoloured bundles, together with the typical stunting: setts from known healthy Q.28 not showing discolouration were inoculated with juice extracted from stalks showing it and the subsequent crops showed both discolouration and stunting.

The discolouration of the vascular bundles caused by ratoon stunting disease occurs generally only in fully differentiated nodes and often only in relatively mature nodes. It is seen at the lower part of the node where the bundles, after running straight and unbranched through the internode, first commence their convolutions and branchings in the intricate fibrous mass of the node. It does not occur in the bundles which go through the nodes without branching nor are the bundles near the rind always affected. The area in which the bundles are discoloured may usually be visualized in three dimensions as a disc or saucer, the amount of concavity, which is always uppermost, depending on the variety. Some varieties as illustrated in Figure 10 show a marked concavity, others are practically flat across the bottom of the node.

The position of the affected areas is such that it may be examined by either a transverse or longitudinal section. In the transverse, discoloured bundles show as small coloured spots arranged in a disc, or in a ring of varying diameter, depending on the position of the section in relation to the concavity of the bottom of the node. The discoloured bundles are seen with the naked eye by this method but a close inspection is necessary and a very sharp, heavy knife is required to make the cross cut through the dense fibres and bundles. The longitudinal section is much more easily made, although here again a sharp knife must be used so that on slicing, the bundles are actually sectioned and the contents exposed. A blunt knife will not cut the bundles and intact bundles do not obviously show the discolouration. The slicings should be made well into the stalk and two or more adjacent nodes should be sliced and examined before making a decision. On occasions a single node may for no obvious reason show symptoms indicative of ratoon stunting, but unless similar symptoms show in an adjacent node a positive diagnosis of ratoon stunting

Fig. 11—Examining a poor crop of mature cane in North Queensland for internal symptoms of ratoon stunting disease.—Photograph by M. H. Barat.

cannot be made. The surface exposed should be examined as soon as cut, although a delay of some seconds often accentuates the general effect of the discolouration. The symptoms cannot be seen if the surface has dried at all, but they can be kept visible for demonstration purposes for some days by complete immersion in cold water or a solution of potassium metabisulphite (potassium pyrosulphite) at a strength of one gm. per litre. Preservatives such as formalin, alcohol and mercuric chloride, either with or without a blanching in hot water, are not effective in preserving the symptoms, since they allow a darkening of the nodal tissues sufficient to mask the symptoms of the disease.

The colour developed in the bundles of diseased stalks varies considerably both in shade and intensity from variety to variety, and is not always constant within the one variety. The greatest discolouration so far seen was found in the Mackay seedling cane, G.176, in which normal healthy bundles are much darker than in other canes. The diseased bundles in G.176 are a dull claret [9] and stand out in marked contrast to the cream to straw coloured ground tissue. A light spectrum orange is a colour common to many varieties. Owing to the range of colours of

bundles in both healthy and diseased cane it is advisable, particularly when examining new varieties or seedling canes, to examine comparable stalks of diseased and healthy material. Very frequently, of course, these are not available and recourse must then be made to inoculation tests into setts of Q.28 or some other susceptible variety.

In some cases there is no change in the general colour of the internodes or nodes associated with the disease, but on occasions these tissues assume a distinct creamish colouration when compared with the paler healthy tissues. Abnormalities such as a light-brown incipient necrosis of the parenchyma of the internode and a marked greyish colour of the node (often associated with excessively wet conditions or aluminium toxicity) are found equally well in both diseased and healthy material.

The shape shown by each individual discoloured bundle in longitudinal sections of the stem will depend on the angle at which it is cut in the slicing. Bundles which are running across the node at right angles to the cut surface will show as small discoloured dots corresponding to transverse sections, while bundles cut longitudinally will show the discolouration for a length of two or three millimetres or even more. Variations between these extremes take the form of various short, straight or bent, discoloured lengths and club- and comma-shaped discolourations.

The colour is confined to the convoluting bundles and cannot be positively identified in the bundles which go through the node without branching or marked bending. For this reason it is difficult to diagnose the disease in the upper nodes of arrowed stalks or in other stalks showing an abnormal amount of pithiness. A hollow or piped stalk does not show the characteristic discolourations in the affected portion.

The number of affected bundles varies within wide limits, but for positive diagnosis in a suspect planting they should be easily found by slicing and, as mentioned above, should present much the same picture from node to node in the fully developed part of the stalk. Discoloured bundles in one node, when there are none in an adjacent node, could not be accepted as being due to the disease, for many factors, some of them little understood, can be responsible for such a picture and it is certainly not typical of ratoon stunting disease.

A hand lens is of little use in the examination of the discoloured bundles caused by ratoon stunting. The magnification combined with the moist, shiny surface of the newly cut or broken cells serves to change the colour values of the bundles in comparison with the surrounding tissue and the essential contrast is largely lost. A similar effect is found under the microscope either by transmitted or reflected light, although of course thin microscopic mounts will demonstrate the plugging of the vascular elements which can also sometimes be seen in fairly thick sections with a good hand lens. For practical purposes, however, magnification is of little value in identifying the disease and time spent in cutting sections to examine closely a comparatively small number of bundles can usually be more profitably spent in slicing a greater number of stalks in a search for more typical symptoms.

Examination of sections under the microscope does, however, show the extent of the colouring within and about the bundles. Coloured plugs are commonly found in the xylem vessels and, to a lesser extent, in the phloem, and the cells adjoining these tissues frequently show a general brownish-red discolouration, which cannot be associated with any specific change in their structure. These discoloured cells outside the bundle proper usually appear dead, but it is not clear whether death follows or precedes the development of the colouring matter.

It has been stressed that in seeking these internal symptoms of ratoon stunting disease only vascular bundles towards the centre of the node should be considered and the affected bundles should show a discolouration, generally of a comparatively light intensity, ranging between a claret red through spectrum orange to a saffron.

Even so there is sometimes issue for confusion with effects produced by other diseases and other damage to the stalk. These often produce reds, some light some very dark, which are outside the range of the colours due to ratoon stunting, but there are occasions when some bundles damaged by these agencies resemble closely those affected with the disease under discussion. Before examining stalks for ratoon stunting it is essential to eliminate as many as possible of the other factors which may produce a similar effect and special care should be taken that only undamaged, apparently healthy stalks are selected for slicing. Bacterial diseases such as leaf scald (*Bacterium albilineans* Ashby) and gumming (*Xanthomonas vasculorum* (Cobb.) Dows.) cause reddening in the bundles, but usually external symptoms or, in the case of gumming, the sweating of gum [15] from cut ends of the stalk or the presence of gum pockets will serve to identify the respective disease. Usually the discolouration with these diseases is more intense than with ratoon stunting. Further points of distinction are that affected bundles show in the internodes as well as in the nodes; in the latter the reddening is not confined to the lower line of the node; and discoloured bundles can be seen in quite immature nodes [53].

The separation of chlorotic streak and ratoon stunting frequently presents a problem since a stalk affected with chlorotic streak does not necessarily show the characteristic streaks on the leaves. The colour of the damaged bundles may be much the same in both diseases but usually in chlorotic streak the colour is to be found right through the node, whereas with ratoon stunting the discolouration is confined to the lower portion of each node. In addition, chlorotic streak usually discolours only a few bundles in each node and the discoloured concave disc formed by discolouration in a number of adjacent bundles at the base of the node is missing.

Infection of the stem with red-rot or rind disease can cause reddening of vascular bundles, as also can large growth cracks, or mechanical damage due to insects or rodents. This discolouration can extend several nodes beyond the seat of the damage and for that reason slicings should always be made on long stalk lengths so as to increase the chance of seeing whether any damage has occurred outside the nodes examined. For the same reasons caution must be exercised in giving a diagnosis of ratoon stunting on the occurrence of discoloured bundles at the base of a stalk. It is always possible that some part of the base of the stalk which is underground could be damaged and so give rise to symptoms in the above-ground parts of the stalk.

Occasionally leaf traces in mature nodes show discolouration to a varying extent but it is not within the colour range for ratoon stunting (usually being much darker), is usually apparent only towards the leaf scar, and is not confined to the lower part of the node.

The age at which stalks show definite reddened bascular bundles as symptoms of ratoon stunting disease shows some variation between different districts and in different years. It would appear that in the Burdekin district, N.Q., at least some varieties do not show symptoms until the cane is approaching or at maturity. At Mackay it has been customary to wait until at least July, *i.e.*, 11 or 12 months after planting or ratooning, but further experience has indicated that the symptoms show well several months earlier when the cane is still growing rapidly under the warm, wet conditions of the monsoonal wet season. At Brisbane, which at a latitude of 27° 30′ S. cannot be regarded as an area of commercial cane production, symptoms show very well in a wide range of varieties from a comparatively early age. Discoloured bundles have been recorded in stalks of many varieties arising from diseased setts as early as four months after planting at Eight Mile Plains Pathology Farm at Brisbane [19]. These particular plants had grown well during the summer months and were showing 18 inches to two feet of cane at the time of the examination. Although the early development of symptoms is quite pronounced the recommendation is made that in seeking for the disease in new

varieties or new areas only mature or near mature cane should be examined. The point is that at the present time there has been much more sectioning done of mature cane than immature and it is felt that at the moment more reliance can be placed on examinations made in the mature cane.

The ease with which the symptomatic discoloured vascular bundles can be found varies considerably. At the one extreme are canes such as Q.28, N.Co.310 and Trojan, in which the damaged bundles are obvious and can be found from an early age; at the other limit are canes such as C.P.29/116 and Q.50 in which the discoloured bundles are often difficult to find even in known badly diseased stalks. The relative obviousness of the discoloured bundles in all varieties approved for planting in Queensland in 1953 is set out in Table VI in comparison with that for the variety Q.28.

The question arises, when carrying out surveys for the presence of ratoon stunting disease by the slicing method, as to the desirability of special selection of stalks for examination. A purely random selection might or might not show the presence of the disease in a block which is only partly diseased, and the chances of finding the disease are increased considerably if some selection is practised along the following lines. Firstly, even in plant crops, it is desirable to seek out the shorter or smaller stools in the block; and, secondly, only primary shoots or apparently primary shoots should be examined. The reason for the selection of the less vigorous stools in looking for symptoms of the disease is obvious and needs no elaboration; the second premise is based on experimental sectioning of a large number of stools which demonstrated that, in a plant crop, a diseased stool always showed the internal symptoms in the primary shoot—they were never found in secondary or younger shoots if the primaries were free. Ratoon stools usually have no obvious primary shoot or shoots, but even so it is recommended that the larger stalks from the poor stools be selected for sectioning.

The internal discolouration in very young cane is a comparatively recent discovery and to date has been confirmed positively in only a limited number of varieties. However, in all instances where comparisons have been possible between definitely diseased and definitely healthy material, the distinction has been apparent. The colour is generally a light coral pink and occurs in a diffuse zone in the central part of the immature nodes with some spreading into the parenchyma of the upper part of the internode. The discolouration shows quite obviously on the node only six millimetres or so from the apical growing point and owing to the general softness of the differentiating tissues in this part of the shoot it is best sought by the same type of longitudinal slicing as used when searching for mature discoloured vascular bundles. The colour is quite light and diffuse and is often not at all obvious unless sections from healthy material of the same variety are examined at the same time.

The discolouration can be found at a very early age in shoots arising from diseased setts. The earliest so far recorded is seven weeks from the date of planting. This was in the summer and the cane had come away very quickly. Nevertheless the shoots were only 18 inches or so above the ground and the growing point terminating the two to three inches of immature cane was still well below ground level. The extremely early development of symptoms has only been recorded consistently with shoots from diseased setts; healthy setts inoculated by the pressure method [6] with diseased juice before planting have given variable results in the early weeks of growth, but a little later have shown the discolouration to the same degree as the diseased material.

The discolouration may be found in young ratoon shoots and also in young suckers arising from the base of mature stools before harvest. The picture presented by sections of these shoots is exactly the same as in those arising from setts.

A few varieties such as, for instance, the South Queensland variety Q.47, do not regularly show the discolouration in the immature cane and an experiment was

designed to test whether lopping mature stalks and inoculating the cut surfaces would give diagnostic symptoms in the shoots coming away from the top buds. Mature stalks were lopped at three-quarters height and a few inches from the ground. Immediately on cutting several drops of diseased juice were placed on the surface and pricked in to half an inch or so with a packing needle. The surfaces were protected from the direct sun for 24 hours and did not dry out unduly. Shoots came away normally from the top buds, but although kept under observation for some three months, by which time they had produced up to four inches of stalk tissue, no symptoms were observed. It was noted also that the cut stalks were not showing reddened vascular bundles when ratooned for further observation.

Since immature nodes in very young shoots show this symptom whether they arise from setts or established stools, it was thought that it might also be seen in the green leaf section of mature or nearly mature cane. Examinations in many diseased stalks of a range of varieties, however, have failed to find it sufficiently consistently for use in diagnosis. Usually the slicings in the immature nodes present the same picture in both diseased and healthy canes and the variations in colour do not appear to be associated with the disease. An exception occurs in the variety Q.44, which consistently shows discolouration in the very young nodes of diseased stalks.

As far as is known no other disease produces the same type of discolouration in the young shoots and the only possibility of confusion lies in the colour developed in some varieties towards the rind in the immature nodes. However, this has not led to any trouble in identification in the varieties examined to date, since in each case it has been confined towards the rind and has never been seen to be spread sufficiently to join with the more centrally placed colour of ratoon stunting.

EFFECT OF ARROWING.

Observations in comparable plantings of diseased and healthy cane have not indicated that ratoon stunting disease has any effect on arrowing except when the diseased cane is suffering severe stunting. It may be a result of the stunting per se that in these instances there is a reduction in the percentage of stalks arrowing. This effect is shown in Fig. 3 and Fig. 12 and, although definite, is hardly of value as a diagnostic symptom.

TRANSMISSION

Setts cut from stools affected with ratoon stunting disease regularly give rise to diseased stools. Sett transmission can therefore be an extremely important method of spreading the disease. Country to country dissemination per medium of the setts was discovered when stools arising from setts imported into Queensland from South Africa and the United States of America and still growing in quarantine here were found infected. This initial presumptive evidence that the disease had actually come from these countries was later confirmed by personal inspection by Bureau officers.

It is a comparatively simple matter to infect originally healthy setts. The knife used to cut the setts is a very efficient instrument for inoculation when smeared with juice by cutting diseased stalks. This has been demonstrated many times in experimental plantings with the typical cane knife in use in Queensland. It has also been shown in spectacular fashion in commercial plantings using the standard cutter planters. These machines are widely used in this State and generally incorporate a knife, or knives moving with a rotating or reciprocating motion, and cutting the stalk into suitable sett lengths as it is lowered down the chute. The stalk being cut is confined horizontally by the vertical chute with the result that the same small section of the blade does all the cutting. This means that that portion of the blade is wet with juice all the time the machine is working. The active

principle of the disease does not therefore have to contend with desiccation and can remain infective on the knife until removed by numerous further cuttings. The virus can withstand considerable dilution and still remain infective (q.v. below) so the infected cutter planter blade can infect a considerable number of setts. One instance of spectacular transmission by the cutter planter was shown when ratoons of one of the yield trials planted in 1947 at Mackay were examined. The trial in question did not occupy the full length of the block and the farmer had planted the rest of the field concurrently with the trial using the same planter. The distribution of disease in the ratoons showed clearly that as the machine moved along the rows after planting plots with diseased cane, it carried infection with it to the extent that up to 60 consecutive setts gave rise to diseased stools, and more

Fig. 12—The variety N.Co.310 is susceptible to ratoon stunting disease. The diseased ratoons are on the left, the healthy on the right.

diseased stools were seen up to 40 yards from where the last diseased sett had been cut in the trial plot. As the machine returned along an adjoining furrow to the trial, there was of course no infection and the stools were healthy right to the edge of the diseased plot.

While knife infection is generally quite efficient, it is not desirable in experimental work to depend for infection on such a method since it is difficult to standardize, and may give rise to erratic results under certain conditions. Dipping the freshly cut ends in an infective solution will also transmit the disease, but generally the most satisfactory method of inoculating setts for experimental work is by means of the small-cup pressure inoculator as described by Bell [6]. The diameter of the cup used is approximately 13 mm., so that it can be used on all normal stalks of commercial varieties.

Fig. 13—Transmission of ratoon stunting by the cutter planter. The row in the centre was infected as the planter moved away from the diseased plot in the foreground.

Several methods have been tried for the inoculation of the growing stool; root and stem inoculations were successful but injections into the growing point and leaf inoculations in earlier trials were not successful, and the results from the repeat trials are not yet to hand.

Root inoculations were made either by cutting the exposed roots with a knife dipped in diseased juice, by cutting the roots off under the surface of diseased juice, or by carefully scraping the earth away from the roots and pouring diseased juice into the small hollow so formed. It is obviously impossible to remove soil from around and between roots, even though that adhering to the root hairs is left intact, without some damage to the roots, so the results of this inoculation do not answer the question as to whether the ratoon stunting disease virus can invade undamaged roots. The Q.28 plants used in these inoculations were less than seven weeks old

and the foliage was only a foot or so in height. The growing point of the primary shoots was still below ground level and there was no above-ground evidence of stooling but there was an abundance of thick, young shoot roots. These only were used for the inoculation, although it was inevitable that some sett roots were damaged in the process. Controls using healthy juice of Q.28, the same variety used as a source of diseased juice, remained healthy as indicated by the lack of discolouration of the immature tissues.

Fig. 14—Pressure inoculation of sett ends.

Stem inoculations have included hypodermic injection into comparatively young stools of Q.28 two to three inches above ground level in shoots showing approximately one foot of cane from ground level to the growing point. These inoculations gave rise to diseased stools but results are not yet available from trials in which mature stalks have been inoculated by placing drops of diseased juice on surfaces exposed by severing the stalk at varying heights. Other current trials include a smearing or pricking into the freshly cut ends of stubble as well as the use of a knife smeared with diseased juice.

The amount of natural spread of ratoon stunting disease is as yet unknown but evidence is accumulating that the disease does not spread rapidly without the agency of man. There have been numerous instances in commercial plantings where stocks of a susceptible variety on one farm have remained disease-free for a number of years while the neighbour across the headland has had the disease all the time. Fields planted in one section with plants from a diseased and in another from a comparatively disease-free source have been grown to second ratoons and at the end of this cycle they still showed a preponderance of disease in the originally diseased. Commercially treated cane has produced crops which have remained apparently free from the disease to maturity in the plant crop, and in some instances they have been inspected in the mature ratoon crop without any evidence of infection. In addition, experimental plantings both at Mackay and at Eight Mile Plains near Brisbane show that the natural method of spread of the disease is relatively inefficient. At Mackay, a crop of G.176 from healthy setts was grown to maturity adjoining diseased cane, then 50 sticks from separate stools were replanted, and both the plant crop and the ratoons of the original planting examined. Only one stool (in the ratoons) was found diseased when these crops reached maturity, and it is possible that this diseased stool became so through contamination rather than natural transmission. Many experimental plantings at Eight Mile Plains, in resistance-trial and other plantings, and involving a wide range of varieties, have remained disease-free although growing in rows adjoining diseased cane for the full plant and first ratoons. Incidentally, the internal symptoms show extremely well at Eight Mile Plains, and canes there are naturally subject to much more thorough and frequent inspections than would be practicable on a commercial farm.

THE CAUSAL AGENT

Identification and Detection.

Many attempts have been made to isolate a microbial causal agent of ratoon stunting disease using a range of media and taking samples from various parts of the diseased plant. Lack of success with these together with an apparent absence of any fungus or bacterium, which would possibly be the cause of the disease, and a tolerance to dilution of infectious juices leads to the conclusion that the causal agent is a virus.

Examination by the ordinary light microscope does not reveal any features which could be of diagnostic value. The discoloured vascular bundles show amorphous masses blocking the xylem tubes with a general discolouration of apparently normal tissue within the affected bundle and the adjacent cells. In attempts to detect the presence of a virus an extensive series of tests and examinations was carried out by the junior author at the University of California during the early part of 1953 but, while some indication of success was obtained, many of the tests were negative. Methods tested included electron microscopy of the crude and partially purified extracts of diseased plants, stream double refraction, ultra violet absorption, electrophoresis, paper chromatography and a special staining technique used successfully with tobacco mosaic.

Electron micrographs did not show any differences between juices from diseased and healthy stalks either at the University of California or when examined by officers of the Commonwealth Scientific and Industrial Research Organization in Melbourne, Victoria. Preparations showed numerous small, roughly spherical particles which were apparently normal plant constituents. If the virus particles were about the same size and shape as these, it would be very difficult to distinguish them unless they could be prepared in a highly concentrated state. This does not appear to be possible by the usual methods of purification which are successful with such viruses as those of false barley stripe and tobacco mosaic. Further preparations were made by precipitating with one-quarter, one-third and one-half

saturated ammonium sulphate, and by adjusting the pH of the juice to 4.2 and 3.5. Precipitates formed were centrifuged off and resuspended in phosphate buffer at pH 7 for examination with the electron microscope and spectrophotometer. No differences between diseased and healthy extracts could be detected.

The extraction of the stalk juice with an equal volume of butanol before ultracentrifuging has been used in the purification of tobacco ring spot virus. The butanol absorbs a large amount of the non-virus material and also throws out the normal plant proteins. After a low-speed centrifuging the aqueous phase is ultracentrifuged to throw down a relatively pure pellet of virus. Nothing could be detected in the aqueous phase with ratoon stunting disease; the butanol phase showed a distinct yellow colour with diseased juice, but was almost clear when healthy juice was used. Ultraviolet absorption studies on these butanol extracts showed the same absorption peak at 275 mμ for both healthy and diseased extracts, but in addition the diseased extract showed a second peak between 330 and 335 mμ which the healthy material did not show. Further work on this finding is to be carried out using extracts from a range of material which was not available in California.

Various extracts of ratoon stunting diseased plants were examined for stream double refraction by methods which show it clearly for tobacco mosaic and barley false stripe, but with negative results. This was not surprising since, if there were sufficient rod-shaped particles to produce the refraction, they would have been detected under the electron microscope. Extracts from ratoon stunting diseased and healthy cane prepared by alternate low- and high-speed centrifugation showed very little movement in the electric field of the electrophoretor at the University of California and no differences could be observed.

Paper chromatograms made from diseased and healthy cane juice showed approximately 15 amino acid spots in both, but in the diseased series several of the slower moving spots were considerably larger than in the healthy, indicating of course a higher concentration of these particular amino acids. Five sugars were recorded, the three most obvious being sucrose, glucose and fructose. The spots for glucose and fructose were much more pronounced from diseased material than from healthy, but further work is necessary to determine whether the differences are a constant feature whenever the disease is present.

Viruses such as tobacco mosaic, potato X, squash mosaic and tomato spotted wilt produce accumulations of virus material in the host plant cells which can be stained to differentiate them from the normal cell components. A method developed by J. G. Bald using Giemsa stain, Orange G and iodine was tried with ratoon stunting disease but without success. Young growing tissue was not available at the time and it is possible that the mature stalk and leaf sections used were not suitable.

A colour test involving heating a small piece of tissue in normal potassium hydroxide and then adding 0.5 per cent. copper sulphate gave some promise of success in early tests but the results were not substantiated on testing a range of varieties.

An attempt to produce an antiserum against ratoon stunting was made by the intraperitoneal injections of rabbits with either a centrifuged, stalk-juice preparation, or a similar extract from leaves of diseased cane. A series of seven injections was made over a period of 21 days and the rabbits bled some 13 days later. The serum was absorbed with twice its volume of healthy juice, prepared by freezing then thawing and crushing healthy stems and leaves, then freezing again, followed by a further thawing and centrifuging. The mixture of serum and juice was incubated at 37° C. for two hours, stored overnight at approximately 5° C., and then centrifuged before use. The absorbed serum was mixed in equal volume with various dilutions of centrifuged diseased and healthy juice from stalks and leaves, then incubated at 37° C. for 1½ hours and stored overnight at 5° C.

Some flocculation occurred with the 1 : 1, 1 :2 and 1 : 4 dilutions of diseased leaf juice after incubation and, after refrigeration overnight, a well defined precipitate settled out in the three dilutions mentioned. The healthy leaf juice series did not form any precipitates. The disease stem juices gave no reaction after incubation but after refrigeration a heavy precipitate formed in the 1 : 1 dilution with lighter precipitates in the other dilutions, even including the maximum dilution tube of 1 : 512. The control tubes with dilutions of juice from healthy stalks all showed some flocculation which, however, was not as dense as and did not settle out as readily as that in the lower dilutions of the diseased series. It is intended to repeat the serological work in the near future.

The experiments outlined above were planned with two general aims in view; firstly, to learn something about the virus itself and, secondly, to provide a ready method of identification of the virus as an aid to investigations into its occurrence in cane and possibly other plants, and as an assistance in the practical application of control measures. Some of the results obtained have given hope that further investigation might establish one or other of the tests as of value for research into ratoon stunting but, in the meantime, the only proved method of determining whether the active virus is present in a plant or an experimental preparation is by inoculation into setts of a susceptible variety such as Q.28.

Distribution Within the Plant.

The distribution of the virus within the plant may be of interest in designing control measures, in concentrating the virus or in considering possible methods of transmission. Detailed studies have not yet been undertaken but tests have shown that the virus occurs in the roots, stems and leaves. Stem juice prepared for inoculation tests consists of a mixture of nodal and internodal juices as squeezed out by the laboratory mill. This has invariably proved infectious when the nodes are showing discoloured vascular bundles. Juice from internodes alone contains the virus, as proved in inoculation tests, and, although it has not been tested, there does not appear to be any reason why the nodal juice should not also be infectious. Extracts from well washed roots and leaves, made by mincing the tissue and then wringing out in a cotton cloth, have proved infectious. The roots used were from poorly grown diseased stools of Q.28, approximately twelve months old, and included both fibrous and the thicker buttress types. The leaves were from the green tops of well grown Q.28 and the sheaths, the tightly rolled spindle and mid-ribs of the older leaves were ecluded.

Ratoon stunting disease virus remains infectious when considerably diluted. An earlier experiment had indicated that stem juice would remain infective when diluted 1 : 1000 and possibly to 1 : 10,000 and similar results were obtained with a recent experiment in which root and leaf extracts were also included.

Presence or absence of the disease was shown by inoculation into ten setts of healthy Q.28 and examination of the resultant stools ten months later, when discoloured vascular bundles were showing clearly in the four feet six inches of

TABLE VII

Diseased Stools/Total Inoculated

	Dilution with Buffer Solution					
Extract	1 : 10	1 : 100	1 : 1000	1 : 10,000	1 : 10^5	1 : 10^6
Leaf	5/10*	5/10*	7/10	2/7	0/8	0/10
Stalk	7/7	5/8*	2/8	0/9	0/10	0/10
Root	2 7	6 10	6 10	2 10	0 9	0 9

* Examined at 6/7 months.

cane in the primary shoots. Dilutions of the juice freshly extracted from roots, stalks and leaves, obtained by the methods outlined in the previous paragraph, were made with a buffer solution. It consisted of 13 gm. KH_2PO_4 and 20 ml. N/5 NaOH per litre of distilled water, which gave a pH of approximately 5.6. A summary of the results obtained is set out in Table VII.

It is obvious that the concentration of virus in leaves and roots is at least as great as that in the stalk.

Inactivation of the Causal Agent.

A knowledge of the tolerance of a virus, or for that matter any other pathogen, to antiseptics is important from both the commercial and experimental points of view. In the case of ratoon stunting the reaction to antiseptics is important commercially because of the ability of the virus to infect per medium of the cutting knife and the possibility that solutions used to spray setts [35, p. 281] before planting may become contaminated. The sterilization of knives, since it is essentially a control measure and involves the causal agent in relation to the environment, rather than the agent itself, is discussed in the section below devoted to control. The possibility of infecting setts with a contaminated spray or dip solution must always be borne in mind in any commercial clean seed scheme since the cutter-planter with attached mercurial spray is well established as a labour-saving device in Queensland canefields. In one type of planter, the spray solution used against pineapple disease [*ibid*] is returned to the tank after wetting the setts. It is quite possible that the chance inclusion of a diseased stalk might provide sufficient infected juice as the stalk was being cut into setts, to contaminate the whole tankful and, of course, infect a large number of setts sprayed subsequently. Another type of cutter-planter in which each sett is dipped in a small bath of mercurial solution poses a similar problem.

A range of antiseptics has been tested both for commercial and for experimental application, the criteria for inclusion being some record as an antiseptic or virus inactivator, ready availability and cheapness. It might be mentioned here that it was soon established that a solution of a mercurial compound similar to the active principle in "Aretan", "Baytan" or "Clerit" in the normal concentration of .015 per cent. mercury did not inactivate the ratoon stunting virus. In testing the antiseptics, solutions were prepared of such a strength that the addition of 25 or 50 per cent. diseased stalk juice would give the desired concentration. Antiseptics which were considered to be of possible commercial use were combined with a mercurial solution of the normal strength. The mixtures were allowed to stand ten minutes before being pressure-inoculated into healthy setts of Q.28 which were subsequently planted and grown to maturity and, in some instances, taken to first ratoons. The results, which were based on the occurrence of discoloured vascular bundles, are set out in Table VIII.

It is apparent that a range of compounds will inactivate the virus when tested under the conditions mentioned but a number of them, at safe inactivating concentrations, would not be practicable as antiseptics on a commercial scale. Ethyl alcohol, as an example, will inactivate the virus in 50 per cent. concentration, but such a mixture is volatile and comparatively expensive: "Aretan," which contains ethoxy or methoxy ethyl mercury chloride as the active agent is dangerous to use at the concentration required and would also be expensive; mercuric chloride is dangerous; the chloroxylenol formulation "Dettol" is somewhat expensive, while formaldahyde, calcium hypochlorite, "Lysol," phenol, "Phenyle" and potassium permanganate are all unpleasant to use and some, in addition, could be dangerous to the operator. At the present time, the quaternary ammonium compound, alkyldimethylbenzyl ammonium chloride, which is the active principle of "Zephiran" [42] holds most promise as a satisfactory inactivator of the ratoon stunting virus.

It is a cationic detergent with bactericidal, emulsifying and wetting properties and may froth seriously when the spray solution in the cutter-planter is recirculated. Zephiran is the only compound of its type so far tested but at least one other, equally available and cheap, is being included in current trials. The possible use of these antiseptics for sterilizing knives is discussed below (q.v. p. 42).

TABLE VIII

Inactivation of Ratoon Stunting Virus by Antiseptics

Antiseptic	Per cent. Concentration	Inoculation Test
Acriflavine	.2*	+
Alcohol ethyl	50	—
"Aretan"	3*	—
	1*	+
Boric acid	5	+
Calcium hypochlorite ..	10	—
"Dettol" (chloroxylenol) ..	1—2.5*	—
	.5*	—
Formaldehyde	4	—
	2	+
"Lysol	.5—2.5*	—
	.1*	+
Mercuric chloride	.1	—
Sodium benzoate ..	2	+
Sodium carbonate ..	10	+
Sodium phosphate (Na_3PO_4)	5, 10	+
Phenol	1, 2.5	—
	.05, .1	+
"Phenyle"	1.66, 2.5*	—
Potassium chlorate ..	5	Germination failure
Potassium permanganate..	1	—
	.1	+
Tannic acid	3	+
Zephiran	.05, .1, .5	—

*Percentage commercial product. Others percentage active principle.

Thermal inactivation of the virus in the sett piece as used for planting is an important method of commercial control of ratoon stunting disease but the sett is a poor conductor of heat, and determinations of the reaction of the virus itself to heat should be made either on expressed juice, as is customary with other viruses, or on small sections of tissue. Attempts to ascertain the temperature at which the virus in cane stalk juice is inactivated have given contradictory results but a series now under way should clarify the position. Discs one-quarter of an inch thick made by cutting with a fine saw transversely across the internodes were placed in 17 per cent. sugar syrup, in order to minimise the loss of cell contents due to osmosis, and held at various temperatures for half an hour. After treatment the discs were crushed and the juice used to inoculate setts of Q.28. The results showed that the virus remained infective after exposure to 49° and 50° C. but treatment at 51° C. and higher temperature caused its inactivation. Results of experiments with commercial setts are referred to on page 33.

An experiment in which undiluted diseased juice was stored in a refrigerator at approximately 40° F. demonstrated that the causal agent could remain infective, as indicated by inoculation into setts of Q.28, for four days: freezing of the juice at −5° F. allowed it to retain its infectivity for at least 20 days.

The Possible Occurrence of Strains.

Considering the present state of knowledge of the disease, it would be undesirable to transfer living, infected material from one country to another for any purpose

whatsoever. No attempt, therefore, is likely to be made by this Bureau to compare the ratoon stunting agent from different countries but, on the other hand, material has been collected from several centres in Queensland, sometimes on the basis of suggested differences of reaction of certain varieties, but in other instances without any such evidence. Diseased stalks were brought from Hambledon and the Northern Experiment Station, where the continuous introduction of varieties from other centres and other countries over many years might be expected to produce a pot-pourri of strains, if such exist: the Lower Burdekin area, just south of Townsville, was of particular interest because of the difficulty of finding symptoms except in comparatively mature cane; samples from the Mackay district were included, since the disease was originally found there; and material from Bundaberg, in South Queensland, was included because the variety Q.50, comparatively resistant further north, showed considerable losses when diseased.

Juice crushed from the stalk samples from the various districts was pressure inoculated into a series of three canes selected following a consideration of the known behaviour to the disease of all varieties available in Brisbane in a disease-free condition. The varieties used were Q.28, which is known to suffer losses from the disease in practically every mill area in the State, Q.50, which is comparatively resistant in North Queensland but apparently not so in South Queensland, and G.176, a Mackay-bred seedling known to be susceptible to the disease. The inoculated setts were planted in April at Eight Mile Plains, but the winter was very open and when the primary shoots were sectioned some seven and a half months after planting the most advanced shoots had produced nearly two feet of cane. The slicings showed identical symptoms in all plots of Q.28, but lack of symptoms in G.176 inoculated with juice from Ayr indicates that the cane in that district may be affected with a strain of the virus different from that in other districts. A similar indication was obtained with Q.50 concerning the strain at the Northern Experiment Station. This showed the characteristic pink nodal discolouration while Q.50 inoculated with diseased juice from other sources showed only a deepening in the normal yellow colour of the node. This slight darkening has been seen in several plantings of diseased Q.50 but it is not sufficiently constant to be a reliable indication of the disease: the variety does not normally show the pink discolouration in the young nodes. A further series of tests using Q.50, G.176 and the North Queensland variety, Q.44, has been planted. The Q.44 was substituted for Q.28 since it has not shown the disease readily in North Queensland, but shows excellent symptoms in the South, and the Q.28 had proved unsatisfactory in the first experiment in that all inoculations gave similar symptoms.

Alternative Hosts.

Inoculation into a range of test plants and the inoculation of setts with extracts of plants affected with certain viruses indicated that the virus of ratoon stunting disease was not one of the well known viruses. Test plants used included tomato (variety Q.2), *Zinnia* (variety Lilliput), *Nicotiana glutinosa*, tobacco (Hickory Prior), *Emilia sonchifolia*, vegetable marrow (Long Cream Runner), and egg plant (Black Beauty). In all cases the inoculation was made by gently rubbing a mixture of freshly expressed juice and celite over the surface of all leaves except the very young and the old. The plants were grown to maturity without showing any abnormalities. Tobacco plants showing tomato spotted wilt and plants of tobacco and *Nicotiana glutinosa* showing cucumber mosaic were used as sources of inoculum for the pressure inoculation of setts of Q.28, but the resultant cane plants gave no evidence of ratoon stunting disease.

A range of grasses is under test at the moment as possible hosts of ratoon stunting disease. Results are not yet to hand from the majority of inoculations but lack of success with inoculations into wheat and oats indicate that these plants cannot harbour the virus. On the other hand, there are indications that maize

may be inoculated successfully with the virus. Young plants of the wheat varieties Charter, Festival and Cailleaux and of the oats variety, Richland, were injected with undiluted stalk juice from diseased Q.28, either into the first fully developed node or, where the stalks were not sufficiently advanced, into the region of the growing point. Approximately five weeks later when the grain had developed to the "soft dough" stage and the leaves were still mostly green, the aerial parts of the plants were minced and the juice, extracted by squeezing through cotton cloth, was used to inoculate disease-free setts of Q.28. As mentioned above, results were negative with all wheat and oats inoculations.

In testing maize as a possible alternative host for ratoon stunting, undiluted diseased juice was inoculated into month-old plants of the three Queensland hybrid corns, Q.23, Q.431 and Q.739. These inoculations, which were made into the tissue above the growing point, were followed 19 days later by a further inoculation into the young stem tissue of the same plants. Twelve weeks later, by which time the plants had tasselled, the above-ground portions were harvested and minced and the juice, extracted through cotton cloth, was used to inoculate setts of Q.28. At time of writing, shoots from these setts are still quite small but those from the inoculated are showing the pink discolouration characteristic of the disease. Samples taken so far in the control planting have been negative, but it is too early to make a complete examination. In the meantime, the experiment is to be repeated.

Inoculation of diseased juice into young plants of a range of sorghums and sudan grasses also did not have any obvious external or internal effect on the inoculated plants. Setts of Q.28 were inoculated with extracts from these plants when approaching maturity but, with one exception, results were negative. The exception was in the plot of Q.28 grown from setts inoculated with an extract from sweet sudan grass.

CONTROL MEASURES

GENERAL.

The measures adopted for the control of sugar-cane diseases in Queensland have been discussed by Hughes [16], who groups them into two classes, viz.: legislative and direct. The legislative measures make provision for the control of the movement of planting material either into the State or from one part to another and, in addition, define the varieties which may be grown in any particular locality. These measures are of general importance in the control of any disease and so have some application to the control of ratoon stunting disease, but the direct methods are the most important at the present time in the fight against this disease. Several of these are of little or no use against ratoon stunting but others have proved so efficient that the commercial control of the disease should, unless some unforeseen obstacle arises, be obtained in every mill district within the next few years.

Roguing, compulsory harvesting and ploughing out, variation of agricultural practices and the use of resistant varieties are of comparatively little importance at the present time in the control of ratoon stunting. Roguing, *i.e.*, the destruction of individual diseased stools, which is such a useful method when dealing with Fiji disease [35], for instance, is of no value with ratoon stunting owing to the absence of an easily identifiable external symptom. The enforced harvesting and/or ploughing out of diseased fields, which in effect amounts to a roguing on a field rather than a stool basis, can be of use in controlling a disease which spreads rapidly from field to field by natural means, such as insects or wind-borne spores. Its use is more limited with ratoon stunting disease which does not spread rapidly, but even so, it may be necessary when the amount of disease in a mill area has been so reduced that only a few diseased fields remain. The alteration of planting and harvesting dates cannot affect the amount of ratoon stunting in a field since it is independent of these factors.

The use of resistant varieties has some application in that the variety Q.50 does appear to be comparatively tolerant to ratoon stunting disease in the Mackay district and further north. It is not, however, an all-purpose cane in the far north, as it is at Mackay, and can only replace the present varieties to a limited extent in these wetter areas. It is used for all purposes at Mackay, where many farmers grow no other variety, but its suceptibility to red rot late in the harvesting season justifies its replacement in part by varieties more resistant to that disease. The varieties Badila and Q.44 appear to have some degree of resistance to infection with the disease, but suffer considerable losses when infected. The position in Queensland then is that there is no range of suitable resistant varieties available to replace the present susceptible canes and, from limited information from other countries, it would appear that the same holds true everywhere that cane is grown. The fact that some variation in susceptibility does occur among commercial clones indicates

Fig. 15—General view of the second ratoons of a ratoon stunting resistance trial. The diseased plots are obvious in comparison with the adjacent healthy plots in many varieties.

that it may be possible to breed varieties resistant to the disease. It would be a long-range project since there is no knowledge of the reaction to the disease of the established breeding lines. The development of new lines of known resistance is a challenge to the cane breeder but the addition of such resistance to all the other features necessary to produce a satisfactory commercial cane does complicate the breeding work considerably. There is some comfort, however, in the fact that at least one major P.O.J. breeding line gave high resistance to another virus, mosaic, combined with a capacity to produce high yielding varieties.

The most satisfactory method of testing reaction to ratoon stunting is by means of properly replicated trials in which the yields from diseased and healthy planting material may be compared. This type of trial involves much time and trouble for both Bureau officers and the farmers on whose properties they are planted, and is only practicable with commercial or near commercial canes. However, it is possible to obtain some indication of varietal reaction from resistance trials in which small single-row plantings of healthy and inoculated setts are compared. The plotlets are

of 25 setts each, and healthy and inoculated are planted in adjoining rows so that direct comparisons may be made across the interspace. At least two pairs of plotlets are used for each variety and there is a scattering throughout the trial of plantings of commercial canes of known reaction such as Q.28 and Q.50. It is unusual to find any differences in the plant crop but the ratoon crop shows stunting in the susceptible canes. Results from such trials are not suitable for statistical analysis, so harvest weights are not taken, reliance being placed on notes as to vigour, stooling and height of cane. A number of these trials have been concluded to date, involving a large range of cultivated and breeding types, and it would appear that the general order of susceptibility of commercial canes is such that serious losses could occur with the present varietal set-up in any district in Queensland —except possibly at Mackay—where more than 80 per cent. of the land is planted to the relatively resistant Q.50. It might be thought that a comparison between crops from healthy and from inoculated setts would not give a true picture of the effects of the disease since, conceivably, inoculation of an originally healthy sett could produce a less stunted stool than a sett taken from a diseased stool. However, although plants from inoculated setts may not be as stunted as those from diseased setts in the plant crop, the effects of the disease are the same in the ratoons.

The methods used at the present time for the control of ratoon stunting disease in Queensland can be classified under the two general headings of provision of clean planting material and the prevention of spread of the disease.

CLEAN PLANTING MATERIAL.

Setts free or apparently free from ratoon stunting disease may be obtained in three ways:—

(*a*) From original seedlings.

(*b*) From disease-free commercial plantings.

(*c*) By a curative treatment of diseased setts.

(*a*) Original Seedlings.

The sectioning of many hundred original seedlings whose parents were known to be susceptible to the disease and in many instances could be expected to have the disease in the actual arrowing stalks used for the crossing did not reveal ratoon stunting in a single seedling. In this examination of complete families, both selectable canes and the poorly grown runts, which would never be considered for selection, were examined. Negative results were also obtained with random sampling through fields of original seedlings. The present knowledge of the transmissibility of the disease should ensure that seedlings reaching commercial status in the future will not have become contaminated during the period of propagation and trial, and so will provide a nucleus of healthy setts for widespread farm planting. Seedlings which are now in course of propagation have generally become contaminated and will have to be rendered disease-free before further testing.

Extreme care is necessary to maintain the seedling canes in their original disease-free condition since, of necessity, they have to be handled many times before they are released for farm plantings. The cane knife is the chief danger since it is very easy to omit the sterilizing of it when cutting canes for planting or as samples for juice analysis. The small sampler used to extract juice from growing canes can also be a potent source of infection in the early stages of selection of a seedling, should there be infected standard canes in the seedling blocks.

(*b*) Disease-free Commercial Plantings.

The first extensive survey for ratoon stunting in Queensland mill areas was made in the latter half of 1952. It showed the disease to be present in all districts but it also revealed that generally only portion of the plantings of each variety in

each district was diseased. This meant that there was usually a sprinkling of fields, sometimes involving a whole farm or the whole of a group of farms, which were apparently free from the disease. These could and did provide a source of plants which, although freer from disease than known diseased blocks, still could not be guaranteed disease-free. It would be impossible to make this guarantee, even in instances where the ratoon behaviour of the fields was known and plantings from them had remained apparently free from the disease, owing to the possibility that small amounts of infection might have remained undetected. The use of these apparently disease-free fields as sources of plants was only a temporary measure until supplies of healthy cane were available, but at least it ensured that the disease position did not deteriorate and that farmers suffered only minor losses, if any, in their newly planted blocks.

(*c*) Curative Treatment of Diseased Setts.

(i) *Hot Water.*—Experiments designed to find a method of rendering diseased setts healthy were initiated comparatively early in the investigations into ratoon stunting disease. The methods tried at first were naturally those which had been proved against other diseases and included external treatment of the setts with mercurials as used for the control of pineapple disease [17] and the hot-water treatment at 52° C. for 20 minutes which inactivates the causal agent of chlorotic streak [5]. These preliminary tests did not yield results, which was not surprising in the light of later knowledge. In 1952 it was announced [49] that crops grown from diseased setts of Q.28 had remained healthy for three years when the setts had been subjected to hot water at 52° C. for one or one and half hours, or at 54° C. for one or one and a quarter hours, or treated in an oven at 50° C. for 24 hours or at 54° C. for eight hours. Results from these and other experiments were the basis for the advice given to Cane Pest and Disease Control Boards [16] that setts should be treated at 54° C. for one hour or at 52° C. for one and a half hours. Sufficient setts to plant three acres were treated by the Lower Burdekin Cane Pest and Disease Control Board late in 1952 and, although this out-of-season planting did not give a satisfactory germination, it must be put on record as the first attempt at commercial hot-water treatment for the control of ratoon stunting in Queensland or, for that matter, in the world. It was soon discovered that many commercial varieties were not as tolerant of hot water as Q.28 and, when large-scale treatment got under way in most districts during the 1953 planting season, the two hours at 50° C. was adopted as standard practice. In recommending the adoption of this time-temperature combination it was realized that the treatment would have to be carried out under carefully controlled conditions for experiments had shown that there was very little room for error. In one experiment, for instance, the reduction in time of treatment from two hours to one and a half hours had led to an odd set remaining infected, while the 10 per cent. diseased setts remaining after treatment at 49° C. for two hours was increased to 80 per cent. when the 49° C. was maintained for only an hour and a half.

The losses being caused by the disease warranted the general introduction of the hot-water treatment even though the recommendations were based on tests with the variety Q.28 only. There is now reason to believe that some varieties, under certain conditions, may require a longer treatment to effect a cure of the disease, and a series of trials has been planted specifically to test this point.

The 1953 planting season saw the first large-scale treatment of diseased planst when 2,115 tons were treated. Some Cane Pest and Disease Control Boards, such as that operating in the Inkerman mill area, on the Burdekin River, which treated 250 tons, handled comparatively large quantities. These yielded good supplies of clean plants for 1954 and Inkerman, at least, had sufficient clean cane for its own requirements and was able to sell some to other areas.

Many difficulties became apparent as the Boards endeavoured to treat large weights of plants for their farmers and, in some instances, many batches received inadequate treatment, chiefly through a lack of appreciation of the necessity to subject every sett to the prescribed temperature for the required length of time. Many of the errors made at the start could be put down to lack of experience and a failure to grasp the mechanical problems involved in obtaining adequate circulation about every individual sett. The process was new to the Pest Board operators and to the Bureau field officers who were exercising a general supervision. In addition, the nature of the plant required was quite different from the types normally used in and about sugar mills and, since new equipment, made according to definite specifications, was generally out of the question owing to the expense and time involved, practically all treatment tanks had to be improvised from material available.

Farmers and others associated with the handling of cane setts were accustomed to the use of jute bags and quite naturally took it for granted that setts cut into bags could be satisfactorily treated in the tank at the mill. These bags of coarse jute fabric with a capacity of three Imperial bushels are widely used for the handling of cereal grains, sugar and fertilizers, under the general name of "corn sack." It was soon found that the comparatively close weave seriously impeded the penetration into and circulation of water within the bag, especially if, as was often the case, the farmer packed the setts in tightly with the idea of getting the maximum number into each bag. Circulation within the bag was improved considerably by cutting holes in the bags, by packing the setts very loosely, and by frequent up-and-down movement of the bags in the water, but even with the best of care, cool spots could occur in the bags, resulting in some setts not receiving the full treatment. The problem was solved by the substitution of metal containers for the bags. These varied in size and construction depending on the shape and size of the tank and the metal available from the mill's stockpile.

The all-metal baskets consist of a flat- or round-iron skeleton of suitable strength covered with galvanized wire netting. They vary in size, and hold up to 200 lb. of cane. They are always rectangular or square in cross section to facilitate packing into the tank and on to the motor trucks for transport. Some are filled by opening a complete side, which is hinged on wire loops, others by the top. In all instances, the cane is completely confined within the basket during treatment; otherwise pithy setts or those which still have some trash clining to them may float up and out of the baskets; besides, any type of sett may be displaced in handling the basket and either escape and sink, or else get tangled with the wire of a neighbouring basket. The wire netting should be of such a mesh as to prevent any setts poking through, and the heaviest gauge obtainable. The number of baskets required for each mill area depends on local conditions, but it can be calculated from a consideration of the methods adopted to get the plants and return them to the farmer after treatment. In some areas the farmers cut the setts into the baskets which are then taken to the tank and, on their return, the setts are emptied directly into the farmer's planter.

The manner in which the setts are packed into the baskets can have a considerable effect on the circulation of water between the setts. If the setts are laid all the one way so that they naturally rest close to each other with a minimum of free space circulation is retarded, and it is strongly recommended that setts either be tumbled higgledy piggledy into the basket as cut without any attempt at orderly arrangement, or else placed in layers only a few setts thick with setts in alternate layers running crosswise.

Besides the improved circulation afforded by the baskets, these containers have one other not unimportant advantage over the bags; that is, that the contents of the basket are open to inspection with the minimum of trouble. To examine

setts in bags properly means a complete unpacking and repacking whereas, in baskets, the cut ends of the setts, where red rot, insect damage and staleness show most obviously, are all exposed ready for inspection. A glance at a basket is sufficient for the operator to assess the suitability of the setts for hot-water treatment and subsequent planting.

The baskets may be lifted individually into and out of the tanks, but several Boards have provided heavy-duty lifting tackle so that several baskets can be placed in a large container and handled as a unit. (See Figures 16 and 17).

The fact that tanks may be loaded with too great a weight of setts can easily be overlooked. A loss in effective circulation, an undue drop in temperature when the setts are first immersed and a slow warming, are concomitants of overloading,

Fig. 16—Left: Putting the finishing touches to a wire basket. Right: A load of filled baskets being lowered into the hot-water treatment tank.

and may result in some of the setts not receiving the full curative treatment. In general, it has been found that the ratio of plants to water should never be greater than one to six or seven; a typical tank of, say, 1,400 gallons would thus have a capacity of about one ton of cane setts per charge. The ratio may be increased when the supply of steam for heating is large and the circulation is very vigorous. In a large tank at a mill in the Mackay district, for instance, efficient operation is obtained with a ratio of approximately one of plants to five of water [14], but this tank, which has a capacity of nearly three tons of plants, is fitted with a six-inch centrifugal pump to circulate the water, and steam is supplied at 80 p.s.i.g. through a one-inch pipe.

The importance of adequate circulation cannot be stressed too much even when all other conditions are ideal for the proper treatment of the setts. The movement of the water in the tanks must be quite active and it is desirable that the pump capacity be sufficient to circulate the entire tankful at least six times an hour.

This rate of circulation gives a marked turbulence as can be seen in the tanks shown in Figures 16 and 17. In operation, the actual surface is not as disturbed as shown since the jets from the outlet pipe are covered when the tank is fully loaded. The water is drawn from pipes at the bottom of the tank, which are usually below the false bottom on which the baskets rest, and forced through holes in pipes along the top on the return.

The source of heat should be adequate for all likely demands from the tank. Usually there is no trouble in obtaining as much steam as required when the mill is crushing, and the steam may be blown directly into the water or through a heating coil. During the slack season, *i.e.*, before the mill starts crushing, the heating of

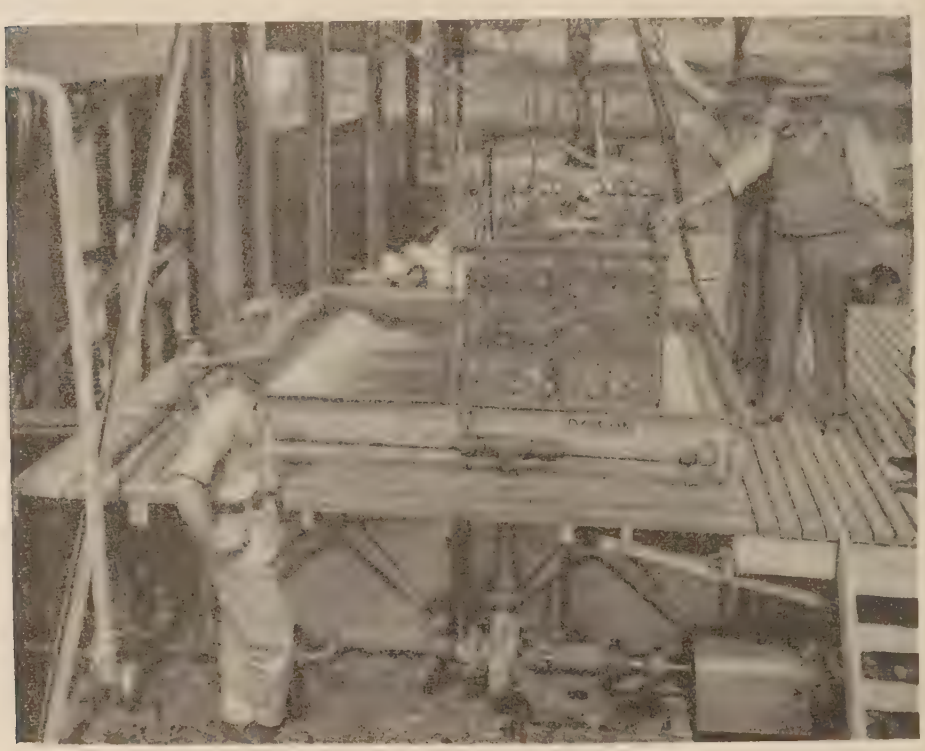

Fig. 17—Note the turbulence in this hot-water tank. The thermometers inserted in the baskets and the tank are for experimental purposes only.

the tanks presents a problem. In some areas, treatment at that time is avoided, in others a steam-cleaning apparatus is used to provide steam. A locomotive would of course be quite suitable, but it would be very expensive in Queensland cane areas owing to the cost of the operational labour. In Taiwan, however, a treatment train consisting of a locomotive and tanks has been developed [27] and, if operated carefully, should be quite efficient (See Fig. 18). At one mill in Queensland the tank is heated by electrical elements, but since they consume electricity at approximately the same rate as the local township, at least when initially warming the water, their use is confined to such times as the mill power house has surplus electricity.

The testing of each treatment plant must be carried out thoroughly to be certain that the circulation is satisfactory and the temperature is uniform throughout

the loaded tank. The type of thermometer used for this testing has to be considered carefully owing to the large volume of both water and setts. The ordinary short-stemmed thermometers are quite unsuitable, as also are various industrial types, such as those used by brewers. The one found most suitable is a long, glass-mercury type fitted into a brass case some four feet in length. The length and weight of the mercury means that these thermometers have always to be calibrated and used in the vertical position but, even with this limitation, they have proved quite satisfactory in determining temperatures at various points in the water and in the sett container. Several are used at the one time as is shown in Figure 17. Once it is established that the treatment plant is efficient, the temperature may be controlled during operational runs by using a thermometer inserted in the circulating system near the pump on the outside of the tank. The installation of a thermostatically controlled steam valve adds considerably to the ease of operation of the tank. The operation of treatment tanks and containers has been discussed in some detail by Wilson [63].

Fig. 18—Control measures against ratoon stunting disease in Taiwan. A mobile hot-water treatment plant.
Photographs by Ju-chi Chou.

The discovery that setts infected with ratoon stunting disease could be "cured" by hot-water treatment and still give a satisfactory germination suggested the possibility that this treatment might have the same effect on other diseases and so could be useful when, for some particular reason, it was desired to use setts from a diseased area. It was already known that setts could be rendered free from chlorotic streak by a much less severe treatment and tests conducted at Eight Mile Plains have shown immersion for two hours in water at 50° C. will also control downy mildew (*Sclerospora sacchari*, Miy.), but not dwarf [4], mosaic, sclerospora (*Sclerospora* sp.) [59] or leaf-scald (*Bacterium albilineans*, Ashby) diseases. For some unexplained reason, the hot-air treatment (q.v. below) will not control downy mildew disease in the sett; it has not been tested against the other diseases mentioned.

The selection of setts for treatment can make all the difference between an even, rapid germination with few, if any, "misses," and an initial failure necessitating a ploughout and replanting. Succulent setts of practically all varieties are likely to fail after treatment and should be avoided, whether the succulence, the soft rind and tender buds are due to immaturity, or to excessively rank growth. It is common knowledge amongst farmers that, generally, the top setts cut from a mature stalk come away more quickly when planted than do those from the central or basal portions of the stalk and, in the ordinary course of events, they make quite good planting material. Unfortunately, however, this type of plant is subject to damage by the heat treatment and a close watch has to be kept that these setts are not sent in for treatment in the hot-water tanks. Apart from the condemnation of the soft, succulent material, the choice of plants for treatment does not differ from

that for commercial planting without treatment. Setts affected with any of the stem rots should be avoided, and the buds and root eyes should be in good condition. There should be no internal insect infestation and the hard setts from the base of old stalks should be avoided.

(ii) *Hot Air.*—Experiments with Q.28 have shown that diseased setts placed in a sealed oven with an air temperature of 53°–54° C. for eight hours, or at 50° C. for 24 hours have been rendered disease-free. The reason for the sealing of the oven is to prevent an undue drying out of the setts, which can impair germination. Germinations are quite satisfactory, even with immature setts, and the method is used in Queensland for small quantities of setts for experimental purposes. There has been no necessity for any further testing of the hot-air treatment, since it obviously had no commercial application in Queensland, but it has been observed that the extension to 16 hours at 53°–54° C. does not seriously affect the vitality of the sett. Internal temperatures of setts in the oven, taken by tightly inserting mercury thermometers in holes bored longitudinally down the middle, indicate that a temperature of 50° C. is reached within two hours when the oven is at 53°–54° C. On this basis the eight hours would appear to be more than equivalent to the two hours at 50° C. given in hot-water.

It is recognized that succulent, immature setts do not germinate satisfactorily after hot-water treatment. In Queensland this obstacle is easily avoided by the use of mature cane which is generally readily available during the normal planting season, but in Louisiana, for instance, no such solution is possible since all cane planted is quite immature. There, advantage has been taken of the fact that immature setts will germinate quite satisfactorily after hot-air treatment and a mobile oven capable of treating one ton of plants per charge has been built [12, 37]. It has handled up to 131 tons in a season.

(iii) *After-Treatment Handling.*—It has been noted that the hot-water treatment of setts is likely to result in poor germinations unless adequate precautions are taken. These involve the careful selection of the setts to be treated, the dipping of the setts in a fungicidal solution before planting and the very careful handling of the treated setts.

Even though every care be taken in the selection of satisfactory planting material, very poor germinations will result with practically all varieties now grown commercially in Queensland unless the heat-treated setts also receive a fungicidal treatment before planting. The effect of the heat is to damage the wounded cells and those immediately beneath on the cut ends of the setts and, although all cells exposed anywhere on the surface of the setts also probably suffer some harm, the cut ends and the root buds are usually the only sites where damage is apparent. It shows in these places as a slight water-soaking which, appearing within a few hours after treatment, resembles that normally resulting after several days in untreated setts. The damage and death of the cells result in the development of ideal invasion points for the numerous sett-rotting organisms in the soil. These will generally destroy the sett before the buds have a chance to move and establish themselves as new stools with root systems independent of the sett; the result is a poor germination. The only practicable way to prevent this is by treatment with a fungicide and the mercurial type as used in Queensland for the control of pineapple disease has proved quite satisfactory [17]. The active organic mercurial is usually methoxy or ethoxy methyl mercuric chloride which is marketed here under the trade names of "Aretan," "Baytan" or "Clerit." Phenyl mercuric acetate has also been used, but not as extensively as the other preparations.

The mercurial may be added to the hot-water tank, when a concentration of .003 per cent. mercury should be used, or the treated setts may be given a dip in a cold bath containing .015 per cent. mercury immediately after treatment. The use of the mercurial in the hot tank does save a double handling of the plants, but

it is more expensive than the other methods because usually a large volume of water is involved, and the mercurial in the hot bath loses its effectiveness even when additions are made to compensate for that lost by absorption on to the setts. Biological tests showed clearly [20] that the mercurial in the hot tanks did not remain in an effective form for longer than five days and that it was necessary to empty completely and refill before charging the tank again if an even more rapid deterioration were to be avoided. These tests were run on a series of tanks using a local strain of *Ceratostomella paradoxa* (de Seynes) Dade, the causal agent of pineapple disease of sugar cane, as the indicator organism. Subsequent to this Leverington [38] successfully applied a potentiometric titration method using potassium iodide to the analysis of mercurials in dilute solution and found that the mercurial in solutions of "Aretan," "Baytan" and "Clerit" could thus be estimated more rapidly and with less trouble than when using the biological test. This titration method could not be used with phenyl mercuric acetate owing to the absence of a definite end point.

The use of a cold dip effects a saving in the amount of mercurial for, although a higher concentration is used, only a comparatively small tank is necessary, and the solution will remain effective for a very much longer period than in the hot tank. Biological assays have shown that the mercurial at a concentration of .015 per cent. mercury will remain stable in the cold for at least three weeks, but when deterioration does occur it happens very quickly, within a day or two. For that reason a regular routine of changing the solution in these tanks is advisable or, alternatively, daily analysis of the mercury content should be made.

The adequate cooling of the heated setts is an item which has, at times, been overlooked in the hot-water treatment. If the setts are taken straight from the hot tank and piled, either in their containers or in bundles, in a confined space, they are likely to remain at a dangerously high temperature for a considerable time and a majority of the setts may be killed. A similar effect is observed if the setts are planted and covered while still hot. Losses due to this prolonged high temperature within the sett may often be avoided by simple modifications in the handling of the setts between treatment and planting. The cold mercurial dip will usually have sufficient cooling effect, providing the tank is not so small that the solution gets heated by the hot setts. Sometimes it may be necessary to hold the treated setts in the open air before further handling. Alternatively the breeze around the setts in baskets on the open back of a motor truck will usually cool them sufficiently before the planting field is reached. Setts treated in bags (which is not recommended, baskets being much preferred), should be taken out of the bags soon after treatment and left loosely piled to cool, and on no account should the hot, filled bags be placed on top of each other. Hosing the hot bags with cold water is usually satisfactory, but concrete floors are not common around treatment plants and the place soon becomes muddy if a sufficient volume of water is used.

Even the hardiest setts are rendered more subject to damage in handling by the hot-water treatment and the farmer should aim at handling all treated setts as carefully as possible. The buds are usually much softer than normal, and any practice likely to damage them should be avoided. They should, for instance, be treated very gently when being transferred to the planter box and, if possible, they should be brought right to the planter in the same basket or container in which they were treated. The best possible soil conditions should be provided and for that reason there should be no out-of-season planting, when climatic and other factors might make germination less reliable than normal. The soil should be in good tilth and the moisture adequate. The soil cover placed over the setts should be as light as possible under the circumstances of temperature and soil moisture, so that the buds will come away as quickly as possible. In brief, if a satisfactory germination is to be expected from treated cane, the best possible conditions must be given it.

In this discussion on the best treatment for the control of ratoon stunting disease, the assumption has been made that only cut setts were brought to the treatment tanks. There is no particular reason why the cane should be cut into setts for treatment and, providing the circulation of water is satisfactory, whole stalks of cane may be treated. The stalks should be loosely tied in bundles and facilities for moving the stalks up and down in the solution should be available.

Varieties show considerable variation in ability to withstand hot-water treatment; the somewhat limited experience here indicates that there is much less variation with the recommended hot-air time/temperatures. Varieties such as C.P.29/116, N.Co.310, Q.28, and Vesta appear to withstand the commercial hot-water treatment quite satisfactorily, while Pindar, Trojan and Q.50 show some

Fig. 19—An effect observed in Pindar following hot-water treatment of the sett for 52°C for 1½ hurs. The bud has germinated with a peg of uniform thickness before shoot rooting and stooling started. Planted November, 1952; examined twelve months later.

variability in resistance: the new cane, Q.55, is very sensitive, as also are several advanced seedlings which are still under test in experimental plantings.

Usually the effect of hot-water treatment is to interfere with or suppress bud and/or root germination of the setts, but a peculiar effect has been observed in several plantings of treated setts of the variety Pindar. In these instances the buds shoot in an apparently normal fashion, although somewhat slowly, but instead of stooling and producing shoot roots against the sett this activity is delayed, with the net result that a peg three to four inches in length is found between the sett and the young stool. The delay in normal growth while this peg is being produced results in the above-ground shoots being very backward, and the stool produced remains stunted. Figure 19 shows a stool with the aerial stalks cut at ground level some twelve months after planting. The peg and the subsequent poorly developed stool are clearly seen.

PREVENTION OF SPREAD OF THE DISEASE.

The prevention of the spread of ratoon stunting both from block to block and from stool to stool within the one block is very important in the control of the

disease. The methods employed depend on a knowledge of the means of transmission and, generally, may be considered from the aspects of sett infection and knife or implement infection.

Ratoon stunting disease is transmitted per medium of the sett, and full consideration must be given to this fact in planning control measures against the disease. Farmers have to be persuaded to use only clean plants as far as possible, and when adequate sources of guaranteed healthy plants become available legislation has to be enacted to force the odd, careless farmers to refrain from using any diseased cane for planting on his property.

Sources of clean plants may be provided by the farmer arranging with the local Cane Pest and Disease Control Board to treat sufficient setts for the planting of a small nucleus. Maybe only a few short rows or an odd corner are planted, but the farmer then has clean plants for the following year, and by continued re-planting has sufficient for the whole farm within a season or two. However, it is often difficult for the farmer to be certain that this clean cane remains free from infection and it is also difficult for Board and Bureau officers to be certain that the cane claimed as clean has not become confused with part of some other planting on the farm, and so rendered suspect. These difficulties largely disappear when the Boards plant specified areas, preferably covering a complete block, with healthy plants and , by arrangement with the farmer, have complete control over the distribution of the plants. The farmer receives some preference in the allocation of the plants, but he is obliged to make a certain percentage available for sale to his neighbours. In practice it has been found that, in any particular district, the Board need plant and supervise only a limited number of plots of clean plants providing they are so situated that they conveniently serve the maximum number of growers. The progeny from them may directly provide practically all the plants required for the district, as on the Lower Burdekin, where the Inkerman Board had a yield of over 10,000 tons of clean plants from an initial planting of a little over 250 acres. When smaller amounts of cane have been hot-water treated a second multiplication is necessary before all requirements are met.

Infected fields may result either from the planting of diseased setts or from the survival of "volunteers" from a diseased crop previously growing in the block. These can provide a source of disease in the next crop and so render abortive all attempts to produce disease-free stocks. The use of volunteers may be minimized by insisting that there should be an adequate fallow after ploughing out the previous crop and, as an extra precaution, the previous crop should not be the same variety as that intended for planting, for then the odd volunteer stool is conspicuous and can be rogued at an early stage of growth.

The problem of sterilizing knives used in cutting cane for harvest or for setts has to be faced if transmission by the cane knives is to be prevented. It might be thought that the inoculation of the cut end as the infective knife sheared through the stalk in cutting setts would leave the diseased juice exposed on the surface for sufficient time to enable antiseptics to render it harmless before it was absorbed by the tissues, especially if the treatment followed immediately after cutting. Preliminary experiments, however, showed very definitely that treatment of the sett after cutting with an infective knife would not prevent transmission, and efforts to control knife transmission were then confined to methods designed to render the knife non-infective.

The method adopted for knife sterilization must be cheap and simple so that it causes the minimum of delay and trouble to the operator; otherwise it is just not done except by the very conscientious worker, who is, however, usually in the minority. Heat is an effective sterilant but it is impracticable to keep a tin of hot water handy to the cutters as they move from an infected block, and the lighting of a fire to heat the knife blade is dangerous under the dry conditions prevailing

at harvest time. The solution appears to lie in the use of some cheap, chemical antiseptic, not unduly unpleasant to handle, comparatively non-corrosive and easily identifiable when prepared for use. A preparation fulfilling these conditions could be placed in tins where cutters would finish a block and could be carried on the utility trucks of such officers as mill cane inspectors and Pest Board Supervisors and others, whose duties might involve collecting canes from various parts of a cane area.

The testing of antiseptics as knife sterilants is not a simple matter and the technique has to be properly standardized before reproducible results can be obtained. It would be preferable if the sterilant functioned without the necessity for washing and scrubbing the blade; accordingly an attempt was made to secure knife sterilization without these added safeguards. In this instance each knife was used for cutting diseased cane until it became tacky and had small pieces of stalk tissue still adhering. It was then immersed in a solution of the sterilizing agent under test and gently swirled around for a period of approximately 15 seconds. However, when these knives were subsequently used for cutting healthy cane it was found that Aretan, 1 per cent., Dettol, 1 per cent., Lysol, 1 per cent., "Phenyle," 2 per cent., and Zephiran, .5 per cent., were not effective in preventing transmission by means of the knife under the rather exacting conditions of the test.

Despite this, investigations are being pursued in an endeavour to ascertain under what conditions satisfactory sterilization of knives can be obtained with any of the readily available antiseptics. Current experiments include longer periods of immersion, swabbing, and actual scrubbing of the knife blade in the various sterilizing solutions.

The knives of the cutter planter [35, pp. 73–77] cannot be sterilized by immersion in a solution without a time-consuming stripping of the implement. Other methods must, therefore, be used, and of these the most convenient are ones in which heat is the sterilizing agent. This may be provided by hot water or by fire. If sufficient hot water (*i.e.*, water close to the boiling point), is poured on to the blades to make them quite hot, the active principle of ratoon stunting disease is destroyed by the washing effect and the heat on the upper surface of the blades, and by heat alone on the lower. The blades may also be sterilized by pouring a few drops of methylated spirits on to them and lighting. There is little danger of starting a cane fire by this method, since the cutter planter should normally be standing in a clean field ready for planting; on the other hand, the flame from the alcohol is invisible in the sun and can cause burns to careless operators. The cutter-planter blades should be sterilized each time after using the machine with diseased or suspect plants.

Some cutter planters in use in Queensland have provision for spraying the setts with a mercurial solution as they drop down the chute from the knife. In one type the solution runs to waste after passing through the nozzles; in the other, it is recovered and circulated again and again. This raises the problem of the contamination of the tank contents and the subsequent infection of the setts by the spraying on the freshly cut ends, should some diseased stalks be put through the planter. The mercurial solution used has no sterilizing effect on the active principle of ratoon stunting disease, but it should be possible to add to the solution some effective sterilant. A number of these have been proved (q.v. p. 28) to destroy the agent in a far higher concentration than could be expected to occur by the inadvertent mixture of a few diseased stalks with healthy ones from an apparently clean source. However, the disadvantages associated with the use of a number of these compounds have already been referred to, and therefore, the recommendation is made that, until a more suitable sterilant is obtained, or until ratoon stunting disease is no longer a threat to the cane crops, the mercurial solution should not be re-used after spraying the setts. Figures have shown that, if suitable

nozzles are used, there is very little to be gained financially by recirculating the sloution and the system is more liable to stoppages than where the solution is allowed to run to waste.

The sterilization of implements other than the cutter planter has not received detailed attention but, in view of the possibility of transmission per medium of the roots, it is considered that all cultivating implements should be cleaned thoroughly after passing through known diseased blocks and the actual working surfaces should be burnt with methylated spirits. The same treatment should also be accorded the cutting parts of harvesting equipment.

THE IMPLICATIONS OF RATOON STUNTING DISEASE

It is generally accepted that genetical deterioration cannot occur in the multiplication and continued growing of an asexually propagated crop, except as a result of mutations. It appears, however, that in sugar cane a "running out" of varieties does occur. This varietal deterioration or, as Brandes suggests [8], this "varietal yield deterioration," has been observed in most sugar producing areas of the world and has been one of the puzzling features of modern cane culture. The picture is of a continual replacement of varieties: new seedling canes are introduced into an area and by outyielding them replace the established canes; these seedlings are themselves displaced by a further batch of new canes, and so on. This should represent progress as shown by an increasing yield per acre from the newer, initially higher yielding canes, but in many instances the expected increase does not occur. There are perhaps many reasons for this and at different times different factors may be responsible. It may be asked whether mutations may cause an alteration sufficiently great as to cause a general decline in the yielding capacity of a particular cane. They can cause such a change in individual stools but, when they do, are always associated with obvious external features which lead the farmer to discard the poor stool as a source of plants. The mutating capacity of any commercial cane is never sufficiently high to lead to a marked change in the overall capacity of a variety, although Li [39] has pointed out that many more mutants occurred than were ever noticed. The reason for varietal yield deterioration must, therefore, be sought in the environment of the variety rather than in the variety itself.

King [28] has discussed several possible causes of varietal yield deterioration in Queensland and statements made by workers who heard this paper presented in 1950 indicated that such deterioration was a problem in many countries. He discussed as possible causes the declining fertility of sugar-cane producing soils, the development of unfavourable physical condition in the soil, the effects of obvious diseases and pests and symptomless or unidentified diseases. He quoted Bell's paper [7], written in 1935, on the "running out" of the variety Q.813, which was shown to be due to the development of a soil microflora inimical to that variety; soil sterilization allowed the variety to yield as well as ever it had done. King [*ibid*] pointed out that the unmistakeable deterioration or loss of yield in Q.28 had already been found to be due to a previously unknown and unidentified disease.

He concluded with the sentence: "It is feasible that the same organism has contributed to senescence of other varieties in the past, but that the tolerance of those varieties had tended to mask the stunting and that the effect has been observed as a gradual diminution of yield and interpreted as a loss of vigour." In a paper on ratoon stunting disease presented to the same Congress of the International Society of Sugar Cane Technologists, Steindl [58] considered that "the disease had been at least partly responsible for the so-called 'running-out' of many varieties in the past."

Later King and Steindl [34] collaborated on a paper which discussed the relationship between varietal yield deterioration and ratoon stunting disease. They

suggested that the presence of a disease such as ratoon stunting in the commercial standard varieties, used for comparative plantings in varietal trials with new seedling canes, should explain the relatively large number of seedlings which are found to be superior to the standard; the development of the disease in a seedling cane by, say, its third or fourth year would likewise explain the sudden loss in vigour which would cause it to be discarded without further trial.

It is accepted by the present authors that ratoon stunting disease has been responsible for "varietal yield deterioration" in many varieties in Queensland. The

Fig. 20—Second ratoons of healthy and diseased C.P.36 13 at Mackay.

effect on new seedlings during the first few propagations has been seen many times during recent years, and it is obvious that a similar effect has been produced in varieties which have passed through all varietal trials and become commercial canes before infection has become widespread in the planting stocks. The disease in Q.28 followed just this course, and had that susceptible variety not become infected or, alternatively, had it not been susceptible to the disease, it is quite likely that ratoon stunting would have remained undetected as a disease to this day. This is not meant to imply that the disease has not had a similar effect on other varieties in the past, and unpublished records in this Bureau show many instances of loss in vigour which, in retrospect, appear to have been due to ratoon stunting. One of particular interest was quoted by Steindl [54], who recalled that as long ago as 1941 an experiment on the Bundaberg Sugar Experiment Station designed to test the yielding capacity of plants taken from phosphate-rich and phosphate-poor soil was rendered abortive by what was probably infection with ratoon stunting in one lot of plants. The variety was P.O.J.2878, then yielding some 55.6 per cent. of the total crop in South Queensland, and the planting of this replicated trial coincided with many complaints that vigour varied with the source of plants. The results obtained from the 1941 trial are reproduced here, not as a verified example of ratoon stunting disease losses, but as an indication of the losses which can be caused by an unspecified disease lacking external symptoms. The trial was planted in February, 1941, was frosted to the ground during the winter of 1941, and then suffered so severely from drought that the crop was too small for harvest in 1942. It was eventually harvested in spring, 1943, when plots from the phosphate-rich sources averaged 19.1 tons per acre with much dead cane, while those from the phosphate-poor averaged 43 tons with all cane sound. Subsequent work and observations have given no indication as to why the plants from the phosphate-rich soil should have been so inferior, and farmers on this fertile alluvial soil type do not consider it necessary to obtain plants from other areas as a regular practice.

Another example of sudden deterioration which was inexplicable at the time is provided by the variety 47–4991 in Hawaii [60]. This cane had shown promise of becoming a good commercial cane, but on some plantations performed poorly. Material collected from good and poor crops planted for observation showed that the latter were affected with ratoon stunting disease while the good crops were healthy.

Apart from the effect of the disease on varietal yield deterioration, ratoon stunting has to be considered with respect to quarantine regulations and to activities concerned with the handling and testing of experimental canes. It is obvious that quarantine regulations requiring only an external examination for pathological symptoms will not cover material affected with ratoon stunting. Even provision for internal examination of setts would not be considered satisfactory either, since it is known that stalks may be diseased, although not showing any vascular discolouration at the time. For movement from one intra-State quarantine area to another the solution is simple in that all setts can be hot-water or hot-air treated either before or after sending; the situation is more complicated when transfer from one country to another is contemplated even with modern air transport available. Heat treatment before despatch is liable to result in failure to germinate at the receiving station and, on the other hand, heat treatment upon receipt is not often practicable owing to growth of the root and shoot buds during transit. The answer to the problem appears to lie in getting plants from guaranteed disease-free sources, although at the present time these are not readily available in many countries, or else heat treating all setts as they come out of the usual period of quarantine in isolation and before they are distributed for propagation and testing. Even if all known precautions are taken against the spread of the disease during quarantine it would be advisable to treat all plants from the one quarantine planting when setts from both disease-free and other sources have been included.

It is fortunate that original cane seedlings are free from the disease and, providing precautions are taken to prevent contamination when taking juice or other samples, they should continue in a disease-free condition until either rejection or eventual commercial propagation. The problem of maintaining the seedlings in a healthy state may be particularly difficult when the plant-breeding activities include cross fertilization, since then arrowing stalks have to be cut (they cannot be broken) from a range of varieties over a large area of growing cane in a very short space of time.

Although the maintenance of all new seedlings in a disease-free condition until testing is possible with the modern knowledge of ratoon stunting, any older seedlings available, which possibly became contaminated and then failed in trials, should all be considered for further testing. The number and status of seedlings thus selected for re-examination will depend on the domestic arrangements of each research centre or experiment station, and whether or not further knowledge of breeding lines or of reactions to other diseases has altered the importance of individual seedlings as prospective commercial canes.

REFERENCES

[1] ABBOTT, E. V., 1953. Private communication to D. R. L. Steindl.

[2] BARAT, H. M., 1954. Private communication to C. G. Hughes, November.

[3] BATES, G., 1954. Hot water treatment of cane plants in the Mulgrave area. Cane Growers' Quart. Bull., Queensland, 17, 3, 78-79.

[4] BELL, A. F., 1933. Dwarf disease of sugar cane. Bur. Sug. Expt. Stat., Queensland. Farm Bulletin No. 8

[5] ————, 1933. A new disease of cane in North Queensland. Cane Growers' Quart. Bull., Queensland, 1, 1, 42-46.

[6] ————, 1935. Two inoculation methods. Proc. Inter. Soc. Sug. Cane Tech., 5th Cong., 199-200.

[7] ————, 1935. Sick soils. Proc. Q. Soc. Sug. Cane Tech., 6th Conf., 9-18.

[8] BRANDES, E. W., 1950. Proc. Inter. Soc. Sugar Cane Tech., 7th Cong., 62.

[9] BRITISH COLOUR COUNCIL DICTIONARY OF COLOUR STANDARDS, THE, 1934. British Colour Council.

[10] BRITISH PHARMACOPOEIA, 1953. Pharmaceutical Press, London, 131.

[11] BUZACOTT, J. H. AND HUGHES, C. G., 1951. The 1951 cane collecting expedition of New Guinea. Cane Growers' Quart. Bull, Queensland, 15, 2, 1-72.

[12] DUNKLEMAN, P. H., 1954. As reported by A. W. Dykes, Sug. Bull., 33, 1, 13-14, Oct. 1.

[13] DYKES, A. W., 1953. Hot air treatment. Sug. Bull., Dec. 15, 92, 95.

[14] GREENAWAY, S., 1954. Notes on the hot-water treatment of cane setts in the Mackay District, 1953. Proc. Q. Soc. Sug. Cane Tech., 21st Conf., 201-205.

[15] HUGHES, C. G., 1939. Alternate hosts of *B. vasculorum*, the causal agent of gumming disease of sugar cane. Bur. Sug. Expt. Stat., Queensland, Tech. Comm. No. 3.

[16] ————, 1950. The control of cane diseases in Queensland. Proc. Inter. Soc. Sugar Cane Tech., 7th Cong., 465-473.

[17] ————, 1950. The treatment of cane setts with mercurial solutions. Bur. Sug. Expt. Stat., Queensland, Farm Bull. No. 11.

[18] ————, 1953. Bur. Sug. Expt. Stat., Queensland, Ann. Rept., 45.

[19] ————, 1953. The Bureau Pathology Farm. Cane Growers' Quart. Bull., Queensland, 17, 2, 57-61.

[20] ————, 1953. Bur. Sug. Expt. Stat., Queensland, Ann. Rept., 43-44.

[21] ————, 1954. The year 1953 in Queensland sugar-cane pathology. Proc. Q. Soc. Sug. Cane Tech., 21st Conf., 207-213.

[22] ————, 1954. Ratoon stunting disease. Comm. Myc. Conf., London.

[23] ————, 1954. Bur. Sug. Expt. Stat., Queensland, Ann. Rept., 68.

[24] ————, 1954. The control of ratoon stunting disease. Inter. Sug. J., Dec., 338-340.

[25] ————, 1955. Ratoon stunting disease trials. Cane Growers' Quart. Bull., Queensland, 18, 3, 71-75.

[26] JU-CHI CHOU, 1954. Private communication to C. G. Hughes, July.

[27] ————, 1954. Communication to Dir. Bur. Sug. Expt. Stat., Queensland.

[28] King, N. J., 1950. Varietal deterioration in Queensland. Proc. Inter. Soc. Sug. Cane Tech., 7th Cog., 56-62.

[29] ————————, 1953. The ratoon stunting disease problem. Cane Growers' Quart. Bull. Queensland, 17, 1, 10-13.

[30] ————————, 1953. The study of ratoon stunting disease. Cane Growers' Quart. Bull., Queensland, 17, 2, 61.

[31] ————————, 1953. A cause of varietal decline. Sug. J., Oct., 24-29.

[32] ————————, 1954. Ratoon stunting disease control in other countries. Cane Growers' Quart. Bull., Queensland, 17, 4, 136.

[33] ————————, 1954. The implications of ratoon stunting disease. Inter. Sug. J., May, 125-127.

[34] ————————, and Steindl, D. R. L., 1953. The relationship between varietal yield deterioration and ratoon stunting disease. Proc. Inter. Soc. Sug. Cane Tech., 8th Cong., 852-860.

[35] King, Norman J., Mungomery, R. W., and Hughes, C. G., 1953. Manual of Cane-Growing. Angus and Robertson, Sydney.

[36] Knust, H. G., 1953. Notes on the heat treatment of cane plants at the Bundaberg Sugar Experiment Station. Proc. Q. Soc. Sug. Cane Tech., 20th Conf., 131-34.

[37] Lauden, L. L. and Nugent, L., 1954. Hot air treatment of sugar-cane in an effort to control stunting disease. Summary from Am. Soc. Sug. Cane Tech., Sug. J., March, 24.

[38] Leverington, K. C., 1953. Unpublished report. Bur. Sug. Expt. Stat., Queensland.

[39] Li, H. W., 1950. Proc. Inter. Soc. Sug. Cane Tech., 7th Cong., 465.

[40] McDougall, W. A., Steindl, D. R. L. and Elliott, J. T., 1948. Variations in primary vigour in the variety Q.28. Cane Growers' Quart. Bull., Queensland, 12, 1, 31-34.

[41] Martin, J. P. and Wismer, C. A., 1954. Ratoon stunting disease of sugar cane. Haw. Sugar Tech., 1954 Repts., 13th Ann. Meeting, 138-140.

[42] Martindale, The Extra Pharmacopoeia, 1952. The Pharmaceutical Press, London, 1, 23rd Ed., 918.

[43] Mungomery, R. W., 1945. Bur. Sug. Expt. Stat., Queensland, Ann. Rept., 22.

[44] ————————, 1947. Bur. Sug. Expt. Stat., Queensland, Ann. Rept., 44.

[45] ————————, 1948. Bur. Sug. Expt. Stat., Queensland, Ann. Rept., 39.

[46] ————————, 1949. Bur. Sug. Expt. Stat., Queensland, Ann. Rept., 41.

[47] ————————, 1950. Bur. Sug. Expt. Stat., Queensland, Ann. Rept., 41.

[48] ————————, 1951. Bur. Sug. Expt. Stat., Queensland, Ann. Rept., 43.

[49] ————————, 1952. Bur. Sug. Expt. Stat., Queensland, Ann. Rept., 43.

[50] ————————, 1953. Obstacles to be avoided in hot-water treating cane setts against ratoon stunting disease. Cane Growers' Quart. Bull., Queensland, 17, 2, 54-56.

[51] ————————, 1954. Clean cane for combating ratoon stunting disease. Cane Growers' Quart. Bull., Queensland, 17, 3, 92-93.

[52] ————————, 1955. Clean seed for planting requirements. Cane Growers' Quart. Bull., Queensland, 18, 3, 81-82.

[53] North, D. S., 1926. Leaf-scald, a bacterial disease of sugar cane. Colonial Sugar Refining Company Ltd., Sydney, Agric. Rept. No. 8 (Technical).

[54] Orian, G., 1954. Communication to Dir. Bur. Sug. Expt. Stat., Queensland, September.

[55] Pembroke, E. A., 1954. Hot-water treated cane plants versus untreated. Cane Growers' Quart. Bull., Queensland, 17, 3, 94.

[56] Robinson, P. E. M., 1953. Private communication to C. G. Hughes, June.

[57] Steindl, D. R. L., 1949. Q.28 disease. Cane Growers' Quart. Bull., Queensland, 12, 4, 191-193.

[58] ————————, 1950. Ratoon stunting disease. Proc. Inter. Soc. Sug. Cane Tech., 7th Cong., 457-465.

[59] ————————, 1953. Sclerospora disease of sugar cane. Proc. Inter. Soc. Sug. Cane Tech., 8th Cong., 952-955.

[60] ————————, 1953. Unpublished report to Dir. Bur. Sug. Expt. Stat., Queensland, Sept.-Oct.

[61] ————————, and Hughes, C. G., 1953. Ratoon stunting disease. Cane Growers' Quart. Bull., Queensland, 16, 3, 79-94.

[62] Story, C. G., 1955. Recovery of Q.28. Cane Growers' Quart. Bull., Queensland, 18, 3, 75.

[63] Wilson, G., 1955. Temperatures inside containers in hot-water treatment plants. Proc. Queensland Soc. Sug. Cane Tech., 22nd Conf., in press.

APPENDIX

Results of Ratoon Stunting Disease Yield Loss Trials

R. S. STEVENS, Racecourse, Mackay.

Soil: Second class alluvial.

Harvested: Plant; September, 1948, at 13½ months.
Ratoon; December, 1949, at 15 months.

Planting Material	Crop	Cane per acre	C.c.s. in cane	Sugar per acre
		tons	per cent.	tons
Q.28 Apparently Healthy	Plant	28.6	16.8	4.80
Diseased ..	Plant	17.9	16.5	2.95
Q.28 Apparently Healthy	Ratoon	27.6	—	—
Diseased	Ratoon	9.6	—	—

The only method of diagnosing ratoon stunting known in 1948 was by the stunting of the stool: it is possible, therefore, that there was some disease in the apparently healthy plots and some healthy stools in the diseased plots —a noting which applies to all ratoon stunting trials planted in 1947 in the Mackay district. The healthy plots exceeded the diseased at the 1 per cent. level of significance in both plant and ratoon crops in this Racecourse trial.

H. IVERS, Rosella, Mackay.

Soil: Poor forest.

Harvested: Plant; November, 1948, at 15 months.
Ratoon; September, 1949, at 10 months.

Planting Material	Crop	Cane per acre	C.c.s. in cane	Sugar per acre
		tons	per cent.	tons
Q.28 Apparently Healthy	Plant	36.0	17.5	6.30
Diseased	Plant	27.3	16.8	4.59
Q.28 Apparently Healthy	Ratoon	20.5	17.1	3.51
Diseased	Ratoon	7.5	16.2	1.22

The healthy plots exceeded the diseased at the 1 per cent. level of significance in both plant and ratoon crops. The figure for the healthy series in the ratoons was not below average for the district although much less than those quoted for three other trials of the same series; some cutter-planter infection occurred at planting and may have affected the yields.

R. YOUNG, Walkerston, Mackay.

Soil: Poor forest.

Harvested: Plant; November, 1948, at 15 months.
Ratoon; December, 1949, at 13 months.

Planting Material	Crop	Cane per acre	C.c.s. in cane	Sugar per acre
		tons	per cent.	tons
Q.28 Apparently Healthy	Plant	30.2	16.8	5.07
Diseased	Plant	23.9	16.2	3.87
Q.28 Apparently Healthy	Ratoon	17.0	11.8	2.01
Diseased	Ratoon	10.0	10.8	1.08

The same remarks apply to this trial as to the previous one. Differences between healthy and diseased were significant at the 1 per cent. level in both plant and ratoon crop.

SUGAR EXPERIMENT STATION, Te Kowai, Mackay.

Trial A.

Soil: Medium poor forest silt loam.

Harvested: Plant; November, 1948, at 14 months.
Ratoon; July, 1950, at 20 months.

Planting Material	Crop	Cane per acre
		tons
Q.28 Apparently Healthy	Plant	40.1
Diseased	Plant	33.1
Q.28 Apparently Healthy	Ratoon	29.6
Diseased	Ratoon	11.4

It was not possible to obtain c.c.s. figures for this trial; the differences for tons of cane per acre were significant at the 1 per cent. level.

SUGAR EXPERIMENT STATION, Te Kowai, Mackay.

Trial B.

Soil: Medium poor forest silt loam.

Harvested: Plant; October, 1948, at 11 months.
Ratoon; June-July, 1949, at 8 months.

Planting Material	Crop	Cane per acre	C.c.s. in cane	Sugar per acre
		tons	per cent.	tons
Q.28 Apparently Healthy	Plant	37.3	14.8	5.52
Diseased	Plant	33.0	14.35	4.74
Q.28 Apparently Healthy	Ratoon	30.3	11.1	3.36
Diseased	Ratoon	10.0	11.5	1.15

The differences in the plant crop were significant at the 5 per cent. level; those in the ratoons at 1 per cent.

ESTATE OF MRS. B. MURRAY, Meringa, Mulgrave Mill Area.

Soil: Red schist.

Harvested: Plant; September, 1954, at 16 months.

Planting Material		Cane per acre	C.c.s. in cane	Sugar per acre	Average length of stalk
		tons	per cent.	tons	inches
Pindar	Healthy ..	47.88	16.08	7.70	102.7
	Diseased ..	40.87	16.34	6.68	89.6
Q.50	Healthy ..	46.10	14.88	6.86	103.6
	Diseased ..	46.38	15.07	6.99	101.1
Trojan	Healthy ..	45.83	15.32	7.02	91.8
	Diseased ..	34.27	16.78	5.75	75.4

The tonnages obtained with all three varieties are much higher than average and indicate the generally favourable growing conditions the trial enjoyed. Q.50 apparently was not affected by the disease, but in each of the other varieties length of stalk and yields of cane and sugar were less in the diseased series at the 1 per cent. level of significance. Differences were not significant in any variety for number of stalks per stool and diameter of stalks.

M. AND C. GHIETTI, Mourilyan, Innisfail.

Soil: Red schist.

Harvested: Plant; December, 1954, at 19 months.

Planting Material		Cane per acre	Sugar per acre	Average length of stalk
		tons	tons	inches
Trojan	Healthy ..	37.56	5.52	79.90
	Diseased ..	33.44	4.52	75.10
Vidar	Healthy ..	39.17	5.90	—
	Diseased ..	35.0	4.96	—

Although cane and sugar yields for both varieties in the healthy and diseased series were different at the 1 per cent. level of significance, and the stalk lengths for Trojan were different at the 5 per cent., factors other than the disease might have affected the results. The plants for the "healthy" plots were not obtained from disease-free stalks but were given the curative hot-water treatment just before planting. This seriously affected the germination and extensive supplying was necessary in this series. The diseased plots germinated well and did not need supplying: they, therefore, came away more evenly than the treated and it was not until March that the treated had caught up with the diseased.

DELECHANTOS AND SON, Giru.

Soil: Grey, alluvial clay loam.

Harvested: Plant; September, 1954, at 15½ months.

Planting Material		Cane per acre	C.c.s. in cane	Sugar per acre	Average length of stalk
		tons	per cent.	tons	inches
Pindar	Healthy ..	41.67	17.23	7.14	103.4
	Diseased ..	35.83	16.94	6.05	95.1
Trojan	Healthy ..	43.25	16.28	7.03	93.3
	Diseased ..	33.42	17.05	5.67	81.4

The differences in tonnage and sugar between the diseased and healthy series of plots were significant at the 1 per cent. level for the variety Pindar; there was the same significance for the cane yield in Trojan, but the sugar yield from the Trojan healthy plots exceeded that from the diseased only at the 5 per cent. level. The number of stalks per stool and the diameter of stalks in the healthy and diseased plots were not significantly different, but the average length of stalk in the healthy plots were greater than that in the diseased at the 5 per cent. level.

MRS. M. T. MARSHALL, Home Hill, Lower Burdekin.
Soil: Alluvial loam.
Harvested: Plant; August, 1954, at 16 months.

Planting Material		Cane per acre	Sugar per acre
		tons	tons
Badila	Healthy	58.23	8.93
	Diseased	57.02	8.57
Oba Badila	Healthy	59.14	9.11
	Diseased	58.43	8.88
Trojan	Healthy	84.65	11.78
	Diseased	83.99	11.64

Differences were not significant in this trial. Ratoon stunting disease was difficult to find in the diseased plot, indicating a low percentage of disease in the commercial planting from which the setts were cut. On the other hand, the results may have some connection with the work on strains from various parts of Queensland (q.v. p. 29), which indicated that the ratoon stunting in the Lower Burdekin district may have been distinct from that in other parts of the sugar belt. In addition, the adequate irrigation of the trial may have had some influence for it is known that irrigation tends to reduce losses in diseased crops.

R. DOBBINS, Maidavale, Lower Burdekin.
Soil: Grey-brown, forest loam.
Harvested: Plant; September, 1954, at 16 months.

Planting Material		Cane per acre	Sugar per acre
		tons	tons
Comus	Healthy	34.98	5.96
	Diseased	36.18	6.09
Pindar	Healthy	49.98	8.60
	Diseased	49.30	8.51
S.J.16	Healthy	47.75	7.67
	Diseased	43.55	7.07

A. STEWART AND COMPANY, Airdmillan, Lower Burdekin.
Soil: Grey, forest loam.
Harvested: Plant; August, 1954, at 15 months.

Planting Material		Cane per acre	Sugar per acre
		tons	tons
Comus	Healthy	49.71	7.97
	Diseased	51.02	8.22
Pindar	Healthy	43.48	7.53
	Diseased	40.75	7.18
S.J.16	Healthy	54.00	8.58
	Diseased	53.58	8.46

The remarks concerning the results obtained from the trial on Mrs. M. T. Marshall's farm apply also to these two other trials in the Lower Burdekin District.

JARROTT BROS., Pleystowe, Mackay.

Soil: Black alluvial loam.

Harvested: Plant; October, 1954, at 14½ months.

Planting Material		Cane per acre	C.c.s. in cane	Sugar per acre	Average length of stalk
		tons	per cent.	tons	inches
P.O.J.2878	Healthy	30.75	16.94	5.21	90.5
	Diseased	26.29	16.85	4.43	84.8
Trojan	Healthy	37.04	17.87	6.62	82.7
	Diseased	29.58	18.15	5.37	75.8

The healthy series of plots in each variety was ahead of the diseased from the start, and at harvest it was obvious that considerable differences existed. The early growth of the crop was hindered by lack of rain and the average yield was much less than to be expected from this excellent soil. Differences in stalks per stool and in diameter of stalks were not significant in either variety, but all other differences between healthy and diseased Trojan in the table above were significant at the 1 per cent. level; the corresponding figures of sugar and cane for P.O.J.2878 were significantly different at the 5 per cent. level, although differences in stalk length for the same variety showed a greater significance.

C. A. H. WESTCOTT, Sunnyside, Mackay.

Soil: Heavy, black clay.

Harvested: Plant; August, 1954, at 12½ months.

Planting Material		Cane per acre	C.c.s. in cane	Sugar per acre	Average length of stalk
		tons	per cent.	tons	inches
Q.50	Healthy	36.78	16.67	6.13	97.7
	Diseased	35.03	17.64	6.18	92.8
N.Co.310	Healthy	34.75	18.27	6.35	98.5
	Diseased	28.31	18.79	5.32	94.5

The harvest figures for Q.50 in this trial agree with results from other trials in that the yields of cane and sugar in this variety are apparently not affected by the disease, although it should be noted that the length of stalk in the healthy plots exceeds that in the diseased at the 5 per cent. level. The effect of the disease on the yields of N.Co.310 are highly significant although the length of stalk showed a difference significant only at the 5 per cent. level. Figures for stalks per stool and stalk diameter were not significantly different in either variety.

S. C. REHBEIN, Bargara, Bundaberg.

Soil: Brown, volcanic loam.

Harvested: Plant; August, 1954, at 11 months.

Planting Material		Cane per acre	C.c.s. in cane	Sugar per acre	Length of stalk	Number of stalks per row
		tons	per cent.	tons	inches	
Pindar	Healthy	25.11	15.01	3.77	73.2	96.3
	Diseased	21.86	15.55	3.4	63.4	89.2
Q.50	Healthy	32.07	13.66	4.38	79.8	116.0
	Diseased	27.65	15.01	4.15	73.8	101.7

Early growth of the trial was hindered by heavy rain, and the later growth by drought, and at harvest the extensive development of stem rots gave erratic c.c.s. figures so that no significance could be attached to the sugar per acre. Cane per acre figures were significant at the 5 per cent. level for both varieties. The average stalk length was greater in the healthy plots of Pindar at the 1 per cent. level and in those of the Q.50 at the 5 per cent., although the number of stalks per row (which is approximately equivalent to a stalks per stool figure) was not significantly different in Pindar and was significant for Q.50 only at the 5 per cent. level.

A. G. HANSEN, Duncraggan Road, Bundaberg.

Soil: Red, volcanic loam.

Harvested: Plant; August, 1954, at 11 months.

Planting Material		Cane per acre	Sugar per acre	Length of stalks	Number of stalks
		tons	tons	inches	
P.O.J.2878	Healthy	29.23	4.00	66.4	90.7
	Diseased	32.67	4.46	66.9	90.2
Q.47	Healthy	34.63	4.86	84.3	112.0
	Diseased	35.43	5.01	77.4	95.7

Analysis of the figures showed a general lack of significance in all differences, although in the variety Q.47 the difference in number of stalks and length of stalk in the healthy and diseased plots was in favour of the healthy at the 5 per cent. level of significance. The diseased material used for each variety was taken from commercial stocks, which subsequent examination showed to be comparatively free from ratoon stunting disease.

WINDERMERE PLANTATION, Bundaberg.

Soil: Red, volcanic loam.

Harvested: Plant; September, 1954, at 19 months.

Planting Material		Cane per acre	Sugar per acre
		tons	tons
C.P.29/116	Healthy	42.7	6.45
	Diseased	38.4	5.79

This randomized block trial also included the varieties Q.47 and Q.50, but germinations in these canes were so poor that figures were not obtained for them. The plots, however, were supplied and the ratoon results may be of value. The differences shown for C.P.29/116 above are not significant.

G. F. THOMASON, Bli Bli, Moreton Mill Area.

Soil: Brown, clay loam.

Harvested: Plant; September, 1954, at 12 months.

Planting Material		Cane per acre	C.c.s. in cane	Sugar per acre
		tons	per cent.	tons
N.Co.310	Healthy	34.16	14.97	5.11
	Diseased ..	36.55	15.17	5.54
Pindar	Healthy	33.56	14.46	4.85
	Diseased ..	31.50	15.08	4.75

The differences shown are not significant and the ratoon results in this wet locality are awaited with interest.